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By

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Declaration

I certify that the dissertation that I have presented for examination for the PhD degree of Graduate School of Economics - Waseda University, is solely my own work.

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Introduction

After the 2007–2008 global financial crisis, uncertainty in general and, more specifically, policy uncertainty have increasingly driven the business cycle fluctuations of the global economy (Baker, Bloom, and Davis 2016; Nicholas Bloom 2014; IMF 2013). Much of policy uncertainty has stemmed from the US economy (IMF, 2013). The current literature has been growing interest in examining the effects of uncertainty on real economic activities (Nicholas Bloom 2014). Theoretically, uncertainty can impair real economic activities through two main channels.[1] The early papers have argued the "wait-and-see" effect channel of uncertainty. To be precise, when investment is irreversible, a firm's optimal investment rule takes on a threshold form. Investment will take place when demand increases to some upper thresholds while disinvestment will occur when demand reaches to some lower thresholds. Because uncertainty raises the upper threshold of investment, the firm is willing to "wait-and-see" rather than undertake a costly action with an uncertain outcome (Bernanke 1983; Nick Bloom, Bond, and Reenen 2007). As a result, this triggers a fall in the level of investment and thus output (Nicholas Bloom 2009).

From the household perspective, higher uncertainty/volatility can induce households to be more concerned about their future labor incomes. For this reason, households tend to increase their precautionary savings by reducing their

[1] A full survey of uncertainty and its effect on the real economy is found in Bloom (2014), Castelnuovo, Lim, & Pellegrino (2017).

consumption (Kimball 1990; Leduc and Liu 2016; Leland 1968). This is likely contractionary to output in the short run, but long run effects are ambiguous. This is because higher savings can spur future investments and thus promote long-run economic growth (Nicholas Bloom 2014). However, in most small open economies, some of these increased savings often flow abroad. For this reason, Fernández-Villaverde et al. (2011) argued that uncertainty can hurt economic growth in a small open economy because the domestic money goes out of the country.

Uncertainty can also harm real economic activities through the "risk premium" channel. High uncertainty/volatility increases "risk premium," thus pushing up the borrowing costs of external finance (C. Arellano, Bai, and Kehoe 2012). This effect is amplified in the presence of financial constraints, which are especially common in developing and emerging economies (Carrière-Swallow and Céspedes 2013)

Pursuing two main channels above, a large number of empirical papers find the adverse effects of uncertainty on real economic activities within a country, for example, investment, output, and employment (Bachmann, Elstner, and Sims 2013; Baker, Bloom, and Davis 2016; Nicholas Bloom 2009; Caggiano, Castelnuovo, and Figueres 2017; Gulen and Ion 2016) and asset prices and financial markets (C. Arellano, Bai, and Kehoe 2012; Brogaard and Detzel 2015; Christiano, Motto, and Rostagno 2014; Gete and Melkadze 2018; Karnizova and Li 2014). These studies have mainly focused the effects of uncertainty in the US economy.

However, the world economy has become increasingly integrated through trade and financial flows. The policy uncertainty of a given leading economy, such as the

US, is not confined within its borders but can spill over to the rest of the world. Thus, another stream of the current literature is to investigate the effects of uncertainty transmitting from advanced economies to emerging markets. This literature often relies on isolated analyses of a target country or a small group of economies. For example, estimating a separate VAR model for 40 advanced and emerging economies, Carrière-Swallow and Céspedes (2013) found that investment and consumption in both advanced and emerging economies are declined significantly following US uncertainty shock. They further stressed that these effects are magnified in the presence of financial constraints. Similarly, using the standard SVAR framework, Colombo (2013) used a novel uncertainty index – named as economic policy uncertainty – proposed by Baker, Bloom, and Davis (2016), and revealed that US policy uncertainty shock significantly exerts a negative effect on inflation and output of the EU in the later. Recently, Kamber et al. (2016) found a negative response of the real economic activities of other major economies and New Zealand to US economic policy uncertainty shock, using a Factor Augmented VAR model. Regarding capital flows, Gauvin, McLoughlin, and Reinhardt (2014) remarked that US uncertainty shock significantly lowers both bond and equity flows into emerging markets. On the contrary, using a rich data set of 26 emerging countries, Gourio, Siemer, and Verdelhan (2015) argued that uncertainty spurs capital flows into emerging economies.

A recently growing stream of the literature is to investigate the effects of the different types of policy uncertainty shock on economic activities. This literature has mainly stressed on the effects of fiscal and monetary policy uncertainty shock. For instance, some studies found that monetary policy uncertainty shock indicates a significantly negative effect on real economic activities (Creal and Wu 2017; Fernández-Villaverde et al. 2011a; Herro and Murray 2013; Husted, Rogers, and Sun 2017; Kurov and Stan 2018; Mumtaz and Zanetti 2013; Sinha 2016a). Other studies have stressed on the role of fiscal policy uncertainty, and they figured out that fiscal policy uncertainty substantially declines the real economic activities (e.g., Born and Pfeifer 2014; Fernández-Villaverde et al. 2015; Johannsen 2014; Mumtaz and Surico 2018; Richter and Throckmorton 2015). More interesting, Mumtaz and Surico (2018) examined the effects of different types of policy uncertainty shock within the US economy, and they found that households and firms are more sensitive to fiscal policy uncertainty shock than monetary policy uncertainty shock.

Another stream of the literature has focusing on measuring uncertainty. Knight (1921) defined uncertainty as people's inability to predict the likelihood of events happening. Uncertainty is a single concept but consists of a mixture of risk and uncertainty (Nicholas Bloom 2014). With the broad definition above, uncertainty measurement is hard, but the literature has proposed a broad range of valid proxies. Nicholas Bloom (2009) first proposed that stock market volatility can be a valid proxy for uncertainty. He argued that the volatility of stock market is well fitted with main economic and political uncertainty events. Furthermore, he noted that stock market volatility is also highly correlated with other uncertainty measurement, for example, cross-sectional spread firm earning and productivity growth. Similarly, Caggiano, Castelnuovo, and Groshenny (2014) used the volatility of 30-day option on the S&P 100 stock index (named as VXO index) to proxy for uncertainty. Another popular proxy is the disagreement among individual and professional forecasters (Lahiri and Sheng 2010; Sill 2012; Bachmann, Elstner, and Sims 2013; Jo and Sekkel 2017). Alternatively, Jurado, Ludvigson, and Ng (2015) argued that policy is more uncertain when it is less predictable. They, therefore, constructed a macroeconomic policy uncertainty for the US using the average of the volatilities of residuals obtained from a factor augmented VAR. Finally, Baker, Bloom, and Davis (2016) proposed an economic policy uncertainty index using new article counts of uncertainty.

In this paper, we emphasize uncertainty in general and, more specifically, policy uncertainty. We therefore prefer to use the economic policy uncertainty index of Baker, Bloom, and Davis (2016). We outline some main advantages of the economic policy uncertainty index over others as follows. First, economic policy uncertainty index describes policy uncertainty well in association with three aspects: (i) *who* makes economic policy decisions; (ii) *what and when* economic policy actions will be taken; and (iii) the *economic effects* of policy actions on both near-term and longer-term concerns (Baker, Bloom, and Davis 2016). Second, these above aspects are published widely in daily newspapers and media and thereby have more power to drive the behaviour of agents (e.g., firms, banks, households, and investors, etc.) regarding investment, consumption, hiring etc. Third, economic policy uncertainty index covers the comprehensive dimensions of uncertainty, such as financial, monetary, fiscal, political, and regulatory policy uncertainty. This, therefore, describes well US uncertainty that has recently driven the wide fluctuations of the global economy.

Baker, Bloom, and Davis (2016) construct economic policy uncertainty index for the US from three sources. The first is to count the word phrase-related economic policy uncertainty published in 10 main newspapers of the US. They search for articles containing the term 'uncertainty' or 'uncertain', the terms 'economic' or 'economy' and one or more of the following terms: 'congress', 'legislation', 'white house', 'regulation', 'federal reserve', or 'deficit' (Baker, Bloom, and Davis 2016). The second source is the Tax Code Expiration Data. They argue that temporary tax expiration are a valuable proxy for uncertainty for businesses and households because Congress often extends them at the last minute, undermining stability and certainty about the tax code (Baker, Bloom, and Davis 2016). The last source is the disagreement from economic forecasters. They gather on the data from Federal Reserve Bank of Philadelphia's Survey of Professional Forecasters. They then measure dispersion in the individual-level data for three of the forecast variables that are directly influenced by government policy, including consumer price index, purchases of goods and services by state and local governments, and purchases of goods and services by the federal government. For each series, they look at the quarterly forecasts data for one year in the future (Baker, Bloom, and Davis 2016).

From the three sources, they then construct the overall index for policy-related economic uncertainty. They first normalize each component by its own standard deviation prior to January 2012. They then compute the average value of the components, using weights of 1/2 on news-based policy uncertainty index and 1/6 on each of other three measures (the tax expirations index, the consumer price index forecast disagreement measure, and the federal/state/local purchases disagreement measure) (Baker, Bloom, and Davis 2016)[2].

We have shown the recent development of the literature of uncertainty in association with real economic activities. This thesis contributes to the current literature by various ways. First, our dissertation relates to the literature of the effects of uncertainty on real economic activities (e.g., Nicholas Bloom 2009; Jurado, Ludvigson, and Ng 2015; Baker, Bloom, and Davis 2016). However, we emphasize on the effects of uncertainty spilling over from the US economy to other countries. This literature is quite restricted in current literature.

Second, some recent papers have been growing interest in examining the spillover effects of uncertainty. However, this literature has relied on isolated analysis of a target country or a small group of countries which do not account for the multilateral nature of international interlinkages. As a result, this has led to the weak robustness of empirical testing (Kalemli-Ozcan, Sørensen, and Yosha 2001; Baier, Bergstrand, and Feng 2014; Georgiadis 2016; Cesa-Bianchi, Pesaran, and Rebucci 2018). Unlike the previous studies, in chapter 2, we improve the empirical methodology by employing a GVAR model in which both direct domestic and indirect foreign impacts, as well as global shocks, are all simultaneously considered. This allows for consistent estimation of the spillover effects of US economic policy uncertainty shock on each country, conditional for both global and foreign impacts to avoid the overestimated and underestimated spillovers.

[2] See Baker, Bloom, and Davis (2016) for a further discussion of the economic policy uncertainty methodology.

Third, a growing strand of the current literature has examined the spillover effects of US uncertainty shock (e.g., Carrière-Swallow and Céspedes 2013; Colombo 2013). However, there are no studies shedding light on why some economies are more vulnerable than others to US economic policy uncertainty shock. As a result, the current literature does not offer new insights into policy interventions to reduce the adverse effects of US economic policy uncertainty shock.

Fourth, a growing trend of the current literature is to examine the effects of the different policy uncertainty on real economies, for example monetary policy uncertainty (e.g., Creal and Wu 2017; Fernández-Villaverde et al. 2011a; Herro and Murray 2013; Husted, Rogers, and Sun 2017; Kurov and Stan 2018; Mumtaz and Zanetti 2013; Sinha 2016a) and fiscal policy uncertainty (e.g., Born and Pfeifer 2014; Fernández-Villaverde et al. 2015; Johannsen 2014; Mumtaz and Surico 2018; Richter and Throckmorton 2015). However, these mentioned studies have focused only on within a country perspective, mainly on the US economy. In chapter 2, we expand this literature to examine how monetary and fiscal policy uncertainty of the US economy spill over to other economies.

Finally, in chapter 3, we propose a new measurement for monetary policy uncertainty. Our approach advances over other exiting measurements by three features. First, unlike to the previous studies, using the newspaper coverage of monetary policy uncertainty or events study (see e.g., Baker et al., 2016; Husted et al., 2017; Kurov & Stan, 2018), we directly construct monetary policy uncertainty from unpredictable interest rate setting of the central bank. This feature is important as interest rate policy, as an important function of economic conditions, has more power in driving the behavior of all agents (e.g., households, firms, banks etc.) in the economy. Second, we construct monetary policy uncertainty based on forward-looking interest rate setting. This approach is more realistic because of allowing the effects of the future economic conditions on current monetary policy decisions (Clarida, Galí, and Gertler 2000; Bernanke 2010). This feature, however, does not capture by the previous studies, for example, using a VAR model with stochastic volatility (see e.g., Mumtaz and Zanetti 2013). Third, after the 2007-2008 global financial crisis, the central banks of advanced economies have implemented various unconventional monetary policies, such as zero low bound interest rate and quantitative easing policy. Therefore, unpredictable interest rate does not enough capture the comprehensive dimensions of monetary policy uncertainty. We address this challenge by using extra two auxiliary sources, including uncertainty about central bank's communication and quantitative easing policy. From three sources, we employ a univariate GARCH model with principle component analysis to construct the overall measurement for monetary policy uncertainty. As a result, our approach is better and cover the comprehensive dimensions of monetary policy uncertainty.

Chapter I. The spillover effects of US economic policy uncertainty on emerging economies: a panel VAR approach

Abstract

This chapter examines the spillover effects of US policy uncertainty shock on emerging economies. Estimating a panel VAR model for a group of 14 emerging economies in different regions, we find that US uncertainty shocks are statistically significant in driving the economic fluctuations in emerging economies. More specifically, US policy uncertainty shocks are the risks, and hence drop the capital inflow, investment, consumption, export, and output of emerging economies. This also induces the currency depreciation and a fall in short-term interest rate of emerging economies to react against US policy uncertainty shocks. Our findings partly help explain the slow recovery of the world economy after the 2007–2008 global financial crisis.

Keywords: Emerging economies, Panel VAR, US uncertainty, Spillover effects, Economic policy uncertainty.

JEL CODE: C33, E20; E32; F02

1.1. Introduction

The global economy has experienced wide fluctuations because of uncertainty in leading economies. This situation has recently intensified when leading economies (e.g., the US) adopted various unconventional macroeconomic policies mix to recover their economic growth after the 2007–2008 global financial crisis. The world economy has increasingly integrated through trades and financial flows. Therefore, uncertainty of a leading economy is not only confined within its borders but also spreads across the world. A large number of studies have examined the effects of economic uncertainty within a country (see e.g., Baker, Bloom, and Davis 2016; Bloom 2009; Jurado, Ludvigson, and Ng 2015). However, few studies have attended to uncertainty transmitting from leading economies to emerging markets (Carrière-Swallow and Céspedes 2013; Han, Qi, and Yin 2016).

This article contributes to the literature by twofold. First, we examine the spillover effects of US policy uncertainty on emerging economies. This literature are quite limited. Second, the previous studies have outlined a few channels through which uncertainty can affect emerging economies, such as investment, consumption (see, e.g., Carrière-Swallow and Céspedes 2013; Kamber et al. 2016; Berger, Grabert, and Kempa 2017). In this paper, we provide the comprehensive channels through which uncertainty in leading economies can influence emerging economies, such as investment, consumption, export and capital flows.

This paper address the following main questions: Does US policy uncertainty spill over to emerging economies? If so, how does it affect and what the main transmission channels are? To answer these questions, We apply a novel uncertainty index – named as Economic Policy Uncertainty (EPU) – recently developed by Baker et al. (2016), into a Panel VAR model of 14 emerging economies. We find that US policy uncertainty shocks are statistically significant in driving the business cycle fluctuations of emerging economies. Particularly, US policy uncertainty shocks are the risks, and thus hindering significantly the capital inflow, investment, export, and consumption, and output of emerging economies. These effects are somewhat large and persistent. We also find that emerging economies experience the currency depreciation and a fall in short-term interest rate following US EPU shock.

The rest of the article is organized as follows. Section 1.2 presents theory and related literature. The empirical methodology is outlined in Section 1.3. Section 1.4 presents the empirical results and discussions. Section 1.5 are the conclusions and implications.

1.2. Empirical Methodology

1.2.1. Uncertainty Measurement

In this chapter, we use the economic policy uncertainty index of Baker, Bloom, and Davis (2016) as a proxy for US policy uncertainty. Furthermore, we also follow Nicholas Bloom (2009) and Caggiano, Castelnuovo, and Groshenny (2014) to use stock price volatility, measured as the volatility index of 30-day option on the S&P 100 stock (named as the VXO index) for robustness analysis.

We prefer the index of Baker, Bloom, and Davis (2016) to other indicators for three reasons[3]. First, we focus on the spillover effects of US policy uncertainty, and thus

[3] The data of US economic policy uncertainty index can access at: http://www.policyuncertainty.com/us_monthly.html.

we prefer to the economic policy uncertainty index of Baker, Bloom, and Davis (2016). Second, this index, constructed by using newspaper coverage of the policy-related economic uncertainty, has more power in driving the behaviour of agents (e.g., banks, firms, households, etc.) in the economy regarding, consumption, investment, and hiring, etc. Third, this index covers the comprehensive dimensions of US policy uncertainty, not only economic and financial but also regulatory and political uncertainty events, which has recently driven fluctuations of the world economy.

We plot the US economic policy uncertainty index in Figure 1.1. As we see from Figure 1.1, US economic policy uncertainty index describes well the main uncertain events in the US economy, for example the Black Monday, the 9/11 terrorist attack, the 2007-2008 financial crisis, the government shutdown etc.

Insert Figure 1.1 here

It is striking to note that the spillover effects of US economic policy uncertainty shocks on each country may be different, depending economic interconnection between the domestic and the US economy. Furthermore, US economic policy uncertainty index, constructed by using the newspaper coverage of policy uncertainty, may be absorbed uncertainty shock of other leading economies (e.g., the EURO). To address these challenges, we modify US economic policy uncertainty index by linking it to each emerging country in our sample using time varying trade weights, constructed over the 1995–2015 period. This approach allows us to acquire the pure spillover effects of US policy uncertainty while isolating uncertainty shocks of other countries and regions. The US EPU (USU) for country i is then constructed as follows:

$$USU_{it} = w_{it}^{US} EPU_t^{US} \quad (1.1)$$

Where w_{it}^{US} are the time varying trade weights between the US economy and the emerging country i at time t, and computed as follows:

$$w_{it}^{US} = \frac{import_{it}^{US_t} + export_{it}^{US_t}}{import_{it} + export_{it}} \quad (1.2)$$

1.2.2. Empirical methodology for quantifying the spillover effects

We develop a Panel VAR model for a group of 14 emerging countries from 1995–2015 period as follows:[4]

$$y_{it} = \phi_1 y_{i,t-1} + \gamma_1 x_t + a_i + u_{it} \quad (1.3)$$

Where y_{it} is the endogenous variables, including US economic policy uncertainty (USU_{it}), real industrial output (IND_{it}), short-term interest rate (R_{it}), real effective exchange rate ($REER_{it}$), consumer price index (CPI_{it}), export (EXP_{it}), foreign direct investment (FDI_{it}), investment (K_{it}), consumption (C_{it}), and traded stock volume ($STOCK_{it}$).[5] x_t is the global oil price index (OP_t) to capture volatilities in the world commodity markets. We also include a time trend to control for global unobservable effects. We assume that the innovations have the following characteristics: $E(u_{it}) = 0$, $E(u'_{it}u_{it}) = \Sigma$, and $E(u'_{it}u_{is}) = 0$ for $t > s$. All the variables are presented in log form, except for FDI, which is measured in term of percent of GDP.

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[4] The details of all countries is provided in Appendix 1.1.

[5] The details of definitions, measurements, and explanations of all variables are provided in Appendix 1.2.

To obtain the same underlying structure for all countries, we first eliminate the fixed effects by differencing, and equation (1.3) becomes as follows:

$$\Delta y_{it} = \phi_1 \Delta y_{i,t-1} + \gamma_1 \Delta x_t + \Delta u_{it} = \Delta X_{it}\delta + \Delta u_{it} \qquad (1.4)$$

For i = 1,..., N and t = 2, ...T, and $\Delta X_{it} = (\Delta y_{i,t-1}, \Delta x_t)$, $\delta = (\phi_1, \gamma_1)$

The equation (1.4) can not be estimated by the ordinary least square due to the presence of the lagged dependent variable in the right hand side, which results in the bias (Nickell 1981). Arellano and Bond (1991) suggested using the predetermined lags of the system variables as instruments to obtain consistent estimators. Let Z be a common set of instruments such that $E(Z'\Delta u_{it}) = 0$, GMM estimators are given by:

$$\hat{\delta}_{GMM} = (\Delta X' Z W_N Z' \Delta X)^{-1} (\Delta X' Z W_N Z' \Delta y) \qquad (1.5)$$

Where, W_N is a weighting matrix assumed to be nonsingular, and symmetric, and positive semi-definite, choose as maximize efficiency.

Since we are interested in the spillover effects of external uncertainty shock (the US) on domestic macroeconomic variables (emerging economies), we impose a short-run restriction using the standard Cholesky decomposition. We follow the current literature to order the variables as follows. First, we order US policy uncertainty (USU) first, implying that US policy uncertainty shocks are exogenous to the macroeconomic fundamentals of our emerging economies (Carrière-Swallow and Céspedes 2013; Colombo 2013). Second, the current literature found that US economic policy uncertainty shocks have a significant effect on the capital inflow and investment of emerging economies (Carrière-Swallow and Céspedes 2013; Gauvin et al., 2014). We, then, order the variables of traded stock market

(STOCK), foreign direct investment (FDI), investment (C) in the next. As a result, US policy uncertainty shocks then can affect consumption (C), export (EXP), and industrial output (IND) of emerging economies. This, in turn, pushes the pressure on the exchange rate (REER) and price index (CPI). Finally, the central banks of emerging countries use their own monetary policies (e.g., interest rate (R)) to stabilize the economy. To provide the robustness of empirical results, we will use different orders of the variables as robustness analysis.

1.3. Empirical results and discussions

We now turn to empirical results. We estimate the Panel VAR model using three lag of the variables as instruments, and the Hansen's J statistic shows that our set of the instruments are valid[6]. We plot the impulse response functions of emerging economies to a one-standard deviation shock of US policy uncertainty in Figure 1.2.[7]

Insert Figure 1.2 here

We first find that capital inflows into emerging economies are estimated to be statistically significant and negative, reaching lowest fall after around one year following US economic policy uncertainty shocks. More specifically, both FDI and equity inflows into emerging economies drop around 0.05% and 1% after one year following US economic policy uncertainty shocks, respectively. We further note

[6] Test of overidentifying restriction: Hansen's J chi2(138) = 146.81548 (p = 0.288)

[7] Our results are robust to: (i) using another uncertainty index measured by the volatility index of 30-day option on the S&P 100 stock index (VXO), (ii) using different orders of the variables. The robustness analysis is provided in Appendix 1.3

that equity flows are more sensitive than FDI flows following US policy uncertainty shocks. Our findings here are highly consistent with the "safe behaviour" type that documented widely in the literature (Kamber et al. 2016). In other words, US policy uncertainty shocks involve risks (Nicholas Bloom 2014), and hence drop capital inflows into emerging economies, where are considered as "less safe" markets (Gauvin, McLoughlin, and Reinhardt 2014).

Second, our findings also confirm the "wait-and-see" effects of uncertainty. In other words, US policy uncertainty shocks are the risks, and thus lead firms and households to postpone their investment and consumption. In particular, investment and consumption are estimated to fall around 0.3% and 0.1% after US economic policy uncertainty shock. However, we further remark that investment channel is more vulnerable than consumption channel. This finding is consistent with the discussion of Bloom (2017) that investors, on average, are more concerned about uncertainty shocks than households are.

Third, by pushing down demands regarding investment and consumption, US policy uncertainty shocks drop both the export and output of emerging economies. More specifically, export and output are estimated to fall after US economic policy uncertainty shocks, reaching the lowest level around 0.15% and 0.2% after one year. Fourth, we reveal that our emerging economies suffer the currency depreciation due to US policy uncertainty shocks. This may stem from a fall in output and capital outflow exposed above. Finally, and fifth, our model predicts that the central banks of emerging economies tend to reduce the short –term interest rate in order to stabilize the economy. Our finding here is highly consistent with the current literature (Kamber et al. 2016)

We next examine the interesting question of how US economic policy uncertainty shocks are important. To answer this question, we consider the forecast-error variance decomposition of the interested variables following US policy uncertainty shock in Table 1.1.

Insert Table 1.1 here

We first underline that the contribution of US policy uncertainty shock in explaining the short-run fluctuation of all considered variables is quite remarkable. In particular, the investment, consumption, export, and output are estimated to respond more strongly to US economic policy uncertainty shocks.

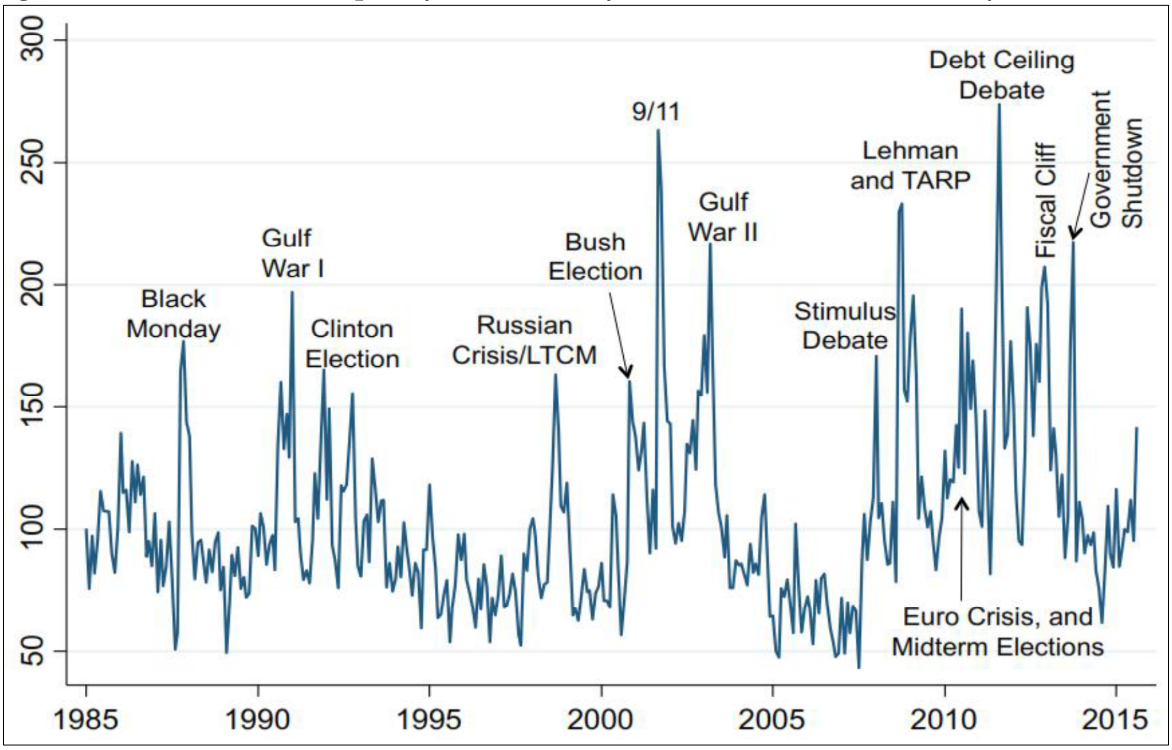
1.4. Conclusions and Suggestions

In this chapter, we investigate the spillover effects of policy uncertainty in leading economies on emerging markets. Taking the US as a typical experiment, and estimating a Panel VAR model for a group of 14 emerging economies, we find a negative reaction of capital inflows, investment, consumption, export, and output of emerging economies to policy uncertainty shock in leading economies. This, in turn, leads to a fall price index and currency depreciation. Our findings partly explain the slow recovery of the global economy after the 2007–2008 global financial crisis.

Our empirical results improve the literature by showing various channels through which policy uncertainty shocks of advanced economies can affect economic activities in emerging economies. However, this chapter also consists of some shortcomings. First, our Panel VAR does not allow to separately examining the spillover effects for each country. This feature is very important because different economic conditions and characteristics among countries and regions can generate different spillover outcomes. Second, our model does not account for multiple interconnections among countries and regions. As a result, empirical testing may be weak robustness. Third, our model are unable to explain why some countries experience lager spillover effects than others following US economic policy uncertainty shock. We will address these shortcomings in chapter 2.

Tables and Figures

Figure 1.1.The economic policy uncertainty index of the US Economy

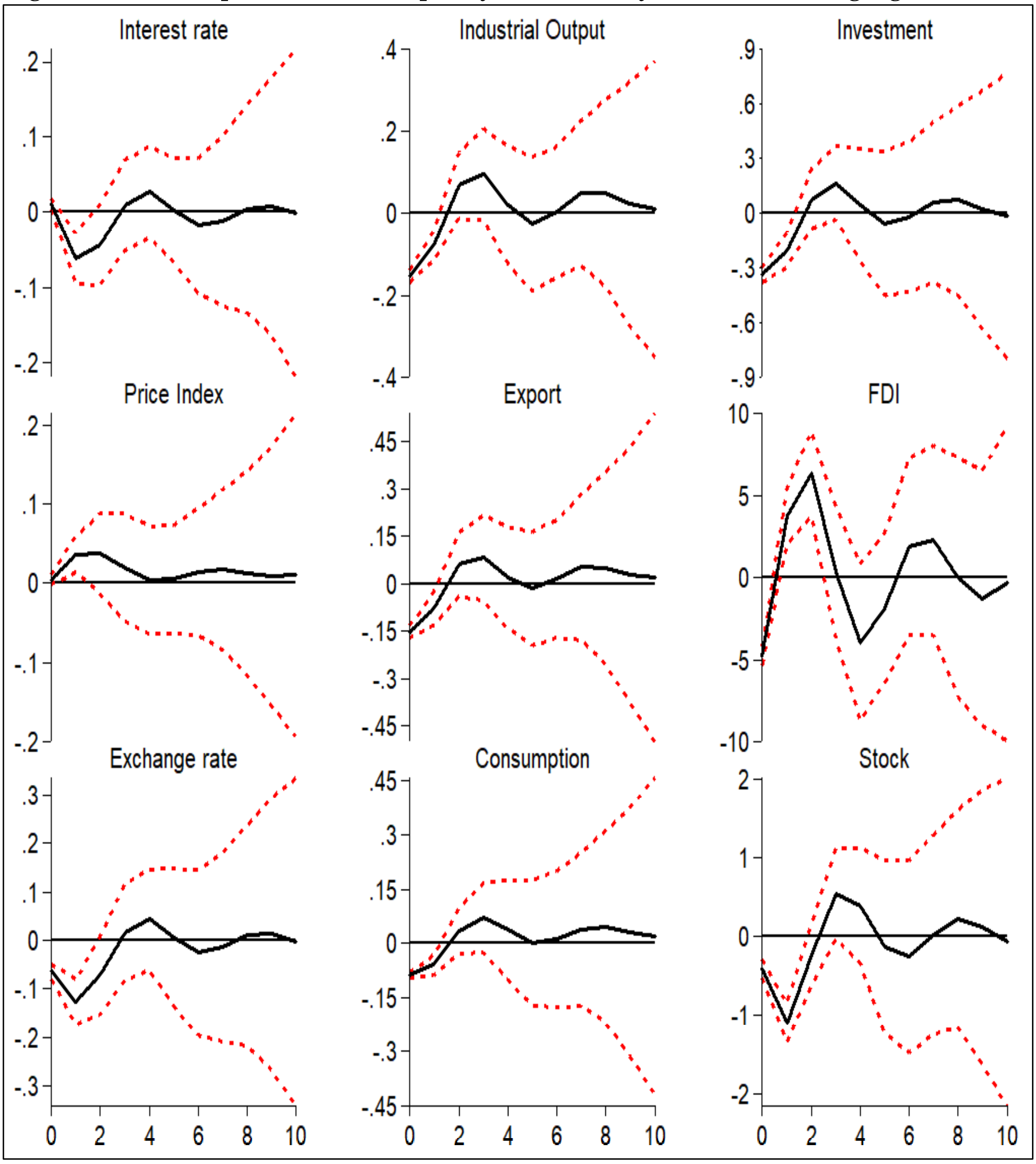


Resource: Baker et al. (2016)

Table 1.1. Forecast error variance decomposition of the considered variables at second year

Variables	FEVD
Consumption	0.46
Price index	0.16
Export	0.40
FDI	0.36
Output	0.52
Investment	0.50
Interest rate	0.31
Exchange rate	0.33
Stock market	0.47

Figure 1.2. The spillovers of US policy uncertainty shock on emerging economies



Notes: The black solid lines display impulse response functions. The red dash lines are the 90% confidence intervals generated through Monte-Carlo simulations with 2000 repetitions. The horizontal axis identifies years. All the variables are presented in log form, except for FDI.

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We thank Professor Baak Saang Joon, the Editor and anonymous referee for valuable comments and suggestions. My acknowledgments go to Professor Hsu Chen Min (the discussant) and the participants at “Korea and World Economy conference - 2017” for valuable comments. Any mistakes made are those of the author alone.

Appendixes

Appendix 1.1. The countries in the model

Table 1.2. The countries included in empirical analysis

China	Argentina
India	Brazil
Korea	Chile
Indonesia	South Africa
Malaysia	Mexico
Philippine	Peru
Singapore	
Thailand	

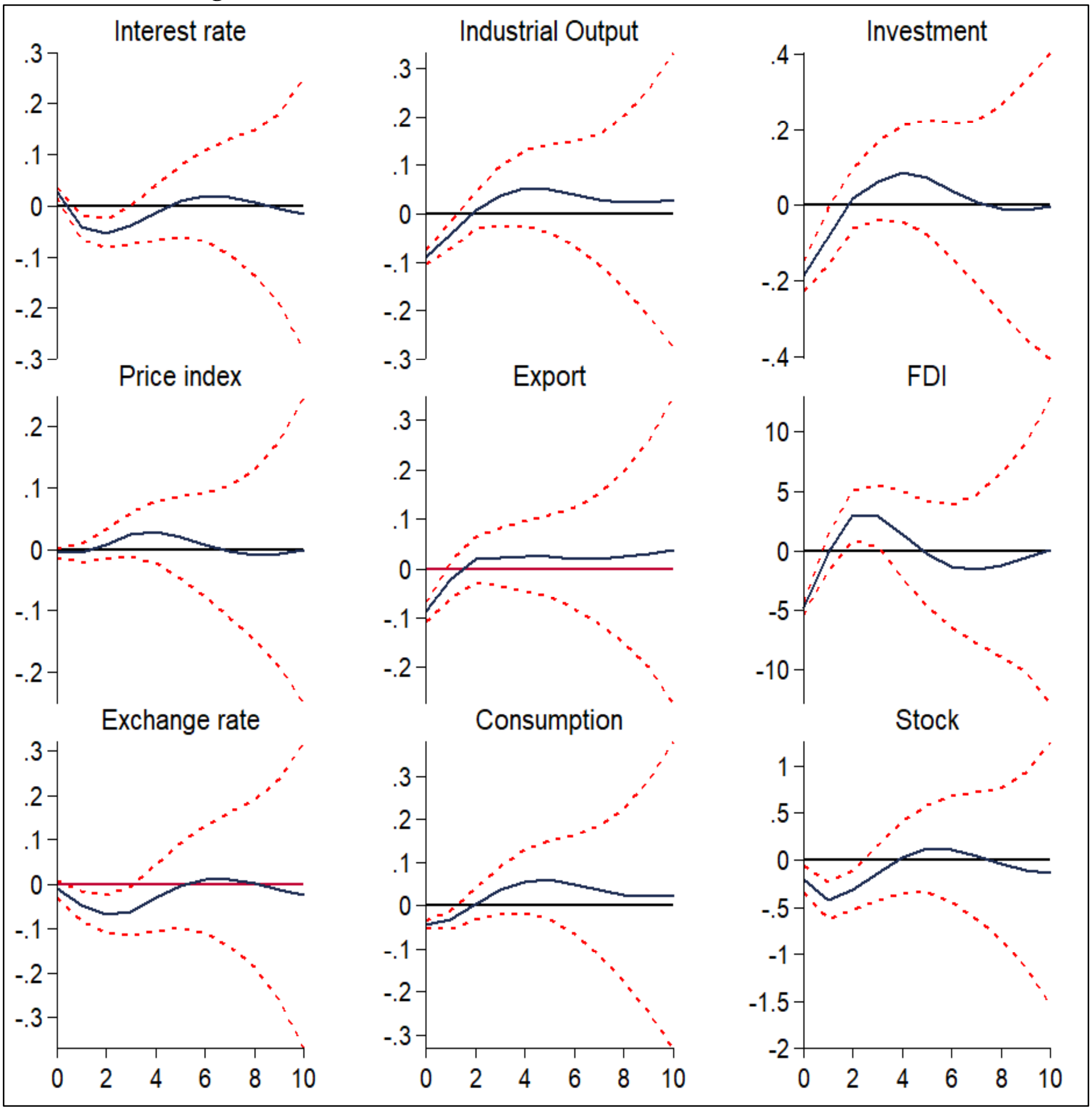
Appendix 1.2. Definitions and measurements of the variables

Table 1.3. Definitions, measurements, and explanations of all the variables

Variables		Explanation
IND	Ln(ind)	ind: industrial output (value-added), constant for 2010
CPI	Ln(cpi)	cpi: consumer price index, (2010=100)
EXP	Ln(exp)	exp: export volume, constant for 2010
REER	Ln(reer)	reer: real effective exchange rate, 2010=100
R	Ln(1+r/100)	r: real interest rate (%)
FDI	As % of GDP	fdi: foreign direct investment in reporting country
STOCK	Ln(stock)	stock: traded stock volume, constant for 2010
C	Ln(cons)	cons: domestic consumption, constant for 2010
K	Ln(inv)	inv: gross fixed capital formulation, constant for 2010
OP	Ln(oil)	oil: the real world oil price index
USU		US economic policy uncertainty
VOL	$\begin{cases} = \text{Ln(VXO) if} > \text{threshold} \\ = 0 \text{ if } \leq \text{threshold} \end{cases}$	VXO: The volatility index of 30-day option on the S&P 100 stock index

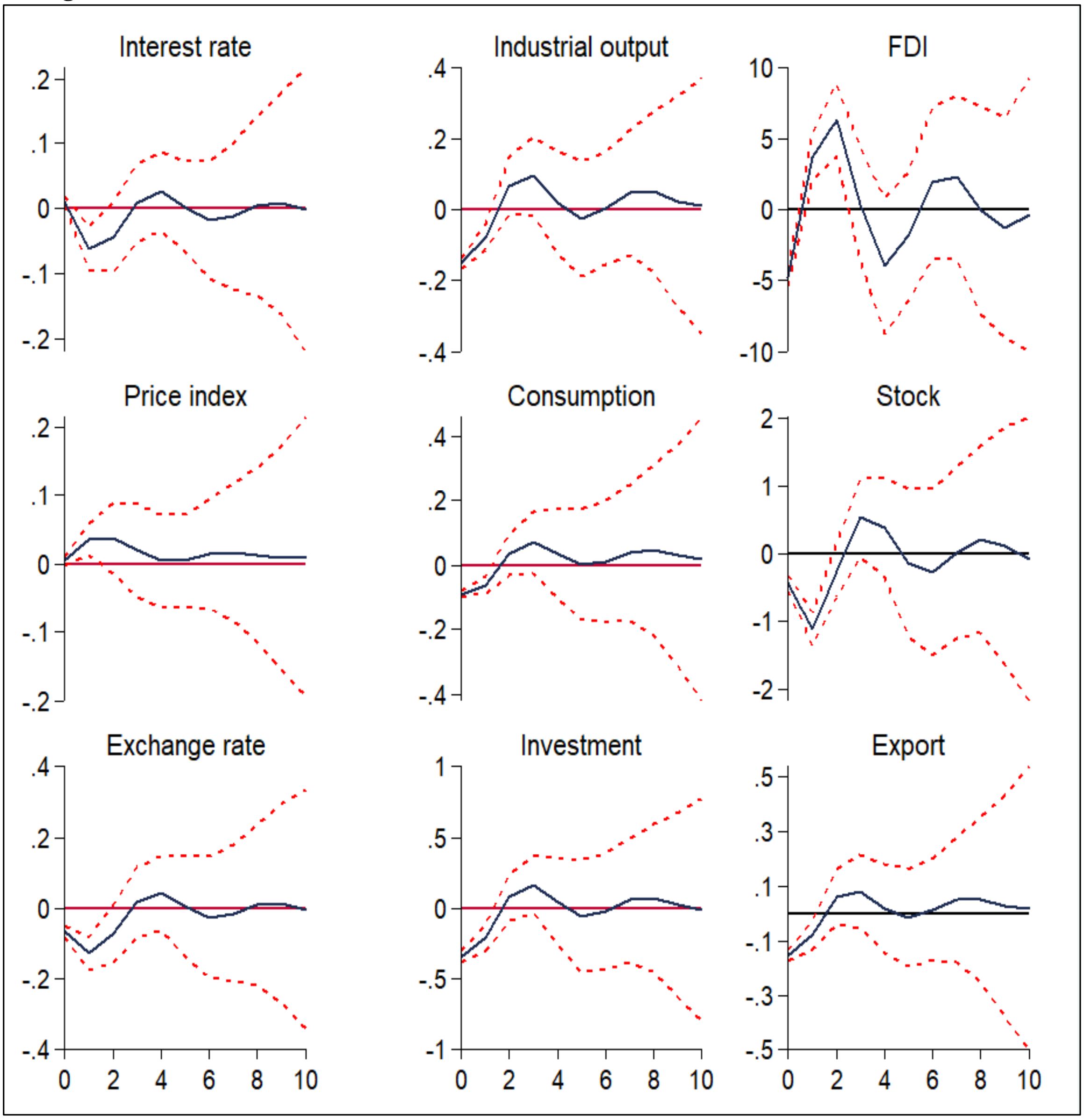
Appendix 1.3. Robust Analysis

Figure 1.3. The spillover effects of US policy uncertainty shock on emerging economies using VXO Index



Notes: The black solid lines display impulse response functions. The red dash lines are the 90% confidence intervals generated through Monte-Carlo simulations with 2000 repetitions. The horizontal axis identifies years. All the variables are presented in log form, except for FDI.

Figure 1.4. The spillovers of US policy uncertainty shocks on emerging economies using different orders of the variables.



Notes: the order of the variables is as follows: EXP, STOCK, FDI, INV, CONS, Y, CPI, and R. The black solid lines display impulse response functions. The red dash lines are the 90% confidence intervals generated through Monte-Carlo simulations with 2000 repetitions. The horizontal axis identifies years. All the variables are presented in log form, except for FDI.

Chapter 2. The spillover effects of US economic policy uncertainty on the global economy: A Global VAR approach

Abstract

Uncertainty in general and, more specifically, policy uncertainty have increased substantially after the 2007–2008 global financial crisis. Much of policy uncertainty has stemmed from the US. In this paper, we examine how US policy uncertainty shock spills over to the rest of the world in a global VAR (GVAR) framework. We find that US policy uncertainty shock is significant in driving the business cycle fluctuations of the world economy. However, the spillovers are small and heterogeneous across countries, which are determined by the different types of US policy uncertainty (e.g., monetary policy uncertainty versus fiscal policy uncertainty) and the receiving country's characteristics (e.g., level of development, trade and financial openness, and quality of institutions). The empirical results offer crucial policy implications for both advanced and developing economies. Improving trade and financial openness and institutional quality can help them to mitigate their vulnerability to US policy uncertainty shock.

Keywords: Economic Policy Uncertainty; Spillover Effects; Institutions; Trade and Financial Openness; Monetary Policy Uncertainty; Fiscal Policy Uncertainty.

JEL codes: E003; F002; F004.

2.1. Introduction

After the 2007–2008 global financial crisis, uncertainty in general and, more specifically, policy uncertainty have increasingly driven the business cycle fluctuations of the global economy (Baker, Bloom, and Davis 2016; Nicholas Bloom 2014; IMF 2013). Much of policy uncertainty has stemmed from the US economy (IMF, 2013). The world economy has become increasingly integrated through trade and financial flows. The policy uncertainty of a given leading economy, such as the US, is not confined within its borders but can spill over to the rest of the world. For this reason, a recently growing strand of the literature has examined the international spillovers of uncertainty (Berger, Grabert, and Kempa 2017; Carrière-Swallow and Céspedes 2013; Gabauer and Gupta 2018; Gupta, Pierdzioch, and Risse 2016; Kamber et al. 2016; Trung 2019; Yin and Han 2014). However, all previous studies in this literature have relied only on isolated analyses of target countries or a very small group of economies; they do not account for the multilateral nature of international linkages among countries and regions. As a result, this can lead to weak robustness of empirical testing (Baier, Bergstrand, and Feng 2014; Cesa-Bianchi, Pesaran, and Rebucci 2018; Georgiadis 2016; Kalemli-Ozcan, Sørensen, and Yosha 2001).

This article asks the following main questions: (1) Does US policy uncertainty drive the business cycles of other economies? (2) If so, how does it affect them and how long does the effect last? (3) Why do some countries experience larger spillovers than others? To answer these questions, we incorporate a novel uncertainty index—the Economic Policy Uncertainty (EPU), recently developed by Baker et al. (2016)—into a GVAR model, extended by Dees et al. (2007).

Using a large data set of 32 economies covering more than 90% of the world GDP, we find that US economic policy uncertainty shock is statistically significant in driving the business cycle fluctuations of the global economy. However, the spillover effects are small and heterogeneous across countries. Overall, for almost all economies, their output first increases for a few months after US EPU shock but then declines after about two to three months later. However, for some other economies, their output declines immediately after US policy uncertainty shock. We further find that trade and capital flows are the main sources for the fluctuations in the output of other economies under US economic policy uncertainty shock. Following US economic policy uncertainty shock, fluctuations in output are partly stemmed from volatilities in capital inflows. This is significant for almost all economies in our model. In addition, we expose that the more economies trade with the US, the more vulnerable they are to US economic policy uncertainty shock. We further find that US economic policy uncertainty shock is statistically significant in driving the fluctuations in the exchange rate, the price index, and the short-term interest rate of other economies. However, these spillover effects are similarly heterogeneous and very small.

Further investigations show that the heterogeneous spillover effects across countries can be attributed to the different structures of US economic policy uncertainty shock (e.g., monetary policy uncertainty versus fiscal policy uncertainty) and the receiving country's characteristics (e.g., level of development, trade and financial openness, and quality of institutions). In particular, we find that US monetary policy uncertainty shock declines significantly the capital flows into other economies and thus this leads to falls in output, inflation, and short-term interest rate, as well as currency depreciation. On the contrary, US fiscal policy uncertainty shock surges the capital flows into other economies for a few months, and thus leading increases in output, inflation, and short-term interest rate, as well as currency appreciation in short-run. Furthermore, we reveal that the receiving country's characteristics are statistically significant in interpreting why some economies experience larger spillovers than others. In particular, financial openness can benefit a country from increasing access to external finance, risk diversifications, and stability of the domestic financial market, thus mitigating its vulnerability to US economic policy uncertainty shock. Similarly, trade openness that focuses on the diversification strategy can help a country to not only gain trade benefits but also reduce the adverse effects of US economic policy uncertainty shock. In addition, improving the quality of institutions can motivate individuals to engage in productive investments and reduce the volatility of capital flows. This, therefore, can help the domestic economy be less vulnerable to US economic policy uncertainty shock.

We advances the current literature in three respects. First, this paper is related to the literature regarding the international spillovers of US uncertainty (see e.g., Carrière-Swallow and Céspedes 2013; Kamber et al. 2016; Trung 2019). In contrast to these papers, we expand this literature by examining the different types of US economic policy uncertainty (e.g., monetary and fiscal policy uncertainty). This issue is quite limited in the current literature. Second, we improve the empirical methodology by employing a GVAR model. The current literature has relied only on isolated analyses of target countries or a very small group of economies, which do not account for the multilateral nature of international interlinkages. As a result, this has led to the weak robustness of empirical testing. Unlike the previous studies, we employ a GVAR model in which both direct domestic and indirect foreign impacts, as well as global shocks, are all simultaneously considered. This allows for consistent estimation of the spillover effects of US economic policy uncertainty shock on each country, conditional for both global and foreign impacts to avoid the overestimated and underestimated spillovers. Third, a growing strand of the current literature has examined the spillover effects of US uncertainty shock. However, there are no studies shedding light on why some economies are more vulnerable than others to US economic policy uncertainty shock. As a result, the current literature does not offer new insights into policy interventions to reduce the adverse effects of US economic policy uncertainty shock. In this article, we show that the spillover effects of US economic policy uncertainty shock are heterogeneous across countries, which can be accounted for by the different types of US economic policy uncertainty shock (e.g., monetary policy uncertainty versus fiscal policy uncertainty) and the specific receiving country's characteristics (e.g., level of development, trade and financial openness, and quality of institutions). For example, the policy-makers in both advanced and emerging economies need to pay more attentions to the different types of US economic policy uncertainty shock because they will generate the different spillover outcomes. Furthermore, improving financial and trade openness, and institutional quality can assist the domestic economy in reducing the exposure to US economic policy uncertainty shock. These implications are important in the current situation when US economic policy uncertainty shock has been intensifying, especially after the 2007–2008 global financial crisis.

The rest of the article is organized as follows. Section 2.2 describes the GVAR methodology and model specifications. Section 2.3 contains the empirical results and discussions. Section 2.4 investigates the spillover effects of the different types of US economic policy uncertainty shock and the role of the receiving country's characteristics and economic structures in determining the spillover effects of US economic policy uncertainty shock. The conclusions and policy implications are outlined in Section 2.5.

2.2. Empirical methodology

2.2.1. Uncertainty measurement

In this chapter, following the chapter 1, we use the economic policy uncertainty index of Baker, Bloom, and Davis (2016)[8]. As shown in the chapter 1, we prefer the index of Baker, Bloom, and Davis (2016) for three main reasons. First, the economic policy uncertainty index describes policy uncertainty well in association with three aspects: (i) *who* makes economic policy decisions; (ii) *what and when* economic policy actions will be taken; and (iii) the *economic effects* of policy actions on both near-term and longer-term concerns (Baker, Bloom, and Davis 2016). Second, the above aspects are published widely in daily newspapers and media and thereby have more power to drive the behaviour of agents (e.g., firms, banks, households, and investors, etc.) regarding investment, consumption, hiring etc. Third, the economic policy uncertainty index covers the comprehensive dimensions of uncertainty, such as financial, monetary, fiscal, political, and

[8] The data of US economic policy uncertainty can access at: http://www.policyuncertainty.com/us_monthly.html.

regulatory policy uncertainty. This, therefore, describes well US uncertainty that has recently driven the wide fluctuations of the global economy.

2.2.2. The GVAR approach to spillover effects

2.2.2.1 The GVAR methodology

The GVAR model consists of a set of country-by-country VARX* models. The VARX*(p,q,r) model of country i, which includes the p-th order of lag of the domestic variables (x_{it}), the q-th order of lag of the foreign variables (x_{it}^*) and the r-th order of lag of the global variables (d_{it}), is presented as below:

$$x_{it} = a_{i0} + a_{i1}t + \sum_{k=1}^{p} \Phi_{ik} x_{i,t-k} + \sum_{\ell=0}^{q} \Lambda_{il} x_{i,t-\ell}^* + \sum_{\ell=0}^{r} \Upsilon_i d_{t-\ell} + u_{i,t} \qquad (2.1)$$

where a, Φ, Λ, and Υ are the coefficient vectors. x_{it}^* are the country-specific foreign variables, constructed by taking the weighted average across all the countries j of the corresponding variables as follows:

$$x_{it}^* = \sum_{j=1}^{N} w_{ij} x_{jt} \qquad (2.2)$$

where the weights satisfy $w_{ii} = 0$ and $\sum_{i=0}^{N} w_{ij} = 1$. Since the weights represent the economic linkages among countries and regions, trade shares are often employed to calculate these weights. d_t are the global variables, for example the crude oil price, which are determined outside the country of interest. For a small open economy, it is more likely that d_t are assumed as exogenous variable. However, for large open economies, such as the US, d_t are often included as endogenous variables.

Consider a simple VARX* $(2,2)$ of country i as below:

$$x_{it} = a_{i0} + a_{i1}t + \Phi_{i1}x_{i,t-1} + \Phi_{i2}x_{i,t-2} + \Lambda_{i0}x^*_{it} + \Lambda_{i1}x^*_{i,t-1} + \Lambda_{i2}x^*_{i,t-2} + u_{it} \quad (2.3)$$

Where a_{i0}, a_{i1}, $\Phi_{i1}, \Phi_{i2}, \Lambda_{i1}, \Lambda_{i2}$ are the matrix of coefficients. The error term u_{it} is $k_i \times 1$ vector assumed to be IID with zero mean and a covariance matrix, denoted as Σ_{ii}.

The equation (2.3) can write in the vector error correction model (VCEMX*) as:

$$\Delta x_{it} = c_{i0} + \alpha_i \beta_i' \left[z_{i,t-1} - \gamma_i (t-1) \right] + \Lambda_{i0} \Delta x^*_{it} + \Gamma_i \Delta z_{i,t-1} + u_{it} \quad (2.4)$$

Where $z_{it} = (x_{it}', \mathrm{x}_{it}^{*\prime})'$, α_i is a $k_i \times r_i$ matrix of rank r_i, β_i is a $(k_i + k_i^*) \times r_i$ matrix of rank r_i. By partitioning β_i as $\beta_i = (\beta_{ix}', \beta_{ix^*}')'$ conformable to z_{it}. The r_i error correction terms in (2.4) can be written as:

$$\beta_i'(z_{it} - \gamma_i t) = \beta_{ix}' x_{it} + \beta_{ix^*}' x^*_{it} - (\beta_i \gamma_i) t \quad (2.5)$$

The VECMX* in (2.4) can be estimated separately for each country/region conditional on x^*_{it}, treating x^*_{it} as I(1) weakly exogenous with respect to the parameters in (2.4) (Dees et al. 2007). Conditional on a given estimate of β_i, the remaining parameters in VARX* model can be estimated consistently by OLS method based on the following equation:

$$\Delta x_{it} = c_{i0} + \delta_i ECM_{t-1} + \Lambda_{i0} \Delta x^*_{it} + \Gamma_i \Delta z_{i,t-1} + u_{it} \quad (2.6)$$

Where ECM is the error correction terms corresponding to the r_i of cointergating relation of the i^{th} country model.

Because the GVAR model is solved for the world as a whole (in terms of a $k \times 1$ global variable vector, $k = \sum_1^N k_i$), it accounts for the fact that all variables are endogenous to the system as a whole. We define a vector z_{it} as $z_{it} = (x_{it}', \mathrm{x}_{it}^{*\prime})'$, the equation (2.3), therefore, can be rewritten as follow:

$$A_{i0}z_{it} = a_{i0} + a_{i1}t + A_{i1}z_{i,t-1} + A_{i1}z_{i,t-2} + u_{it} \qquad (2.7)$$

Where $A_{i0} = (I_k, -\Lambda_{i0})$, $A_{i1} = (\Phi_{i1}, \Lambda_{i1})$, and $A_{i2} = (\Phi_{i2}, \Lambda_{i2})$.

We now use the link matrix W_i, the country-specific trade weights w_{ij}, to obtain the identity as:

$$z_{it} = W_i x_t \qquad (2.8)$$

Where $x_t = (x'_{0t}, x'_{1t}, ..., x'_{Nt})'$ is the $k \times 1$ vector of all endogenous variables in the system, and W_i is a $(k_i + k_i^*) \times k$ matrix. Using the identity in (2.8), we can rewrite (2.7) as:

$$A_{i0}W_i x_t = a_{i0} + a_{i1}t + A_{i1}W_i x_{t-1} + A_{i2}W_i x_{t-2} + u_{it} \quad (2.9)$$

All the countries then are stacked to yield the model of x_t as:

$$G_0 x_t = a_0 + a_1 t + G_1 x_{t-1} + G_2 x_{t-2} + u_t \qquad (2.10)$$

Where

$$G_0 = \begin{pmatrix} A_{00}W_0 \\ A_{10}W_1 \\ \vdots \\ A_{N0}W_N \end{pmatrix};\ a_{i0} = \begin{pmatrix} a_{00} \\ a_{10} \\ \vdots \\ a_{N0} \end{pmatrix};\ a_{i1} = \begin{pmatrix} a_{01} \\ a_{11} \\ \vdots \\ a_{N1} \end{pmatrix};\ G_1 = \begin{pmatrix} A_{01}W_0 \\ A_{11}W_1 \\ \vdots \\ A_{N1}W_N \end{pmatrix};\ G_2 = \begin{pmatrix} A_{02}W_0 \\ A_{12}W_1 \\ \vdots \\ A_{N2}W_N \end{pmatrix};\ u_t = \begin{pmatrix} u_{0t} \\ u_{1t} \\ \vdots \\ u_{Nt} \end{pmatrix}$$

Because G_0 is a known and invertible matrix, we can multiply (2.10) by G_0^{-1} to obtain the GVAR (2) model as:

$$x_t = b_0 + b_1 t + F_1 x_{t-1} + F_2 x_{t-2} + \varepsilon_t \quad (2.11)$$

Where $F_1 = G_0^{-1}G_1, F_2 = G_0^{-1}G_2, b_0 = G_0^{-1}a_0, b_1 = G_0^{-1}a_1, \varepsilon_t = G_0^{-1}u_t$

2.2.2.2. Model specification

Our GVAR model covers 32 countries and estimates over the period from 2000-M1 to 2013-M12. Following the standard literature, we construct an EU block consisting of eight countries. The datasets for the EU are constructed as cross-sectionally weighted averages of domestic variables, using purchasing power parity GDP weights averaged over the 2009–2011 period. Our GVAR model, therefore, includes 25 country/region-specific VARX* models. The details of included countries and regions are displayed in Appendix 2.1. It is worthy to note that all the included countries cover more than 90% of the world's GDP, consisting of both key advanced and emerging economies in different regions. Thus, our GVAR model is very representative of the global economy and is able to capture the multilateral nature of global interlinkages.

Regarding key variables in our GVAR model, core domestic variables (x_{it}) are the industrial product index (ind_{it}), the consumer price index (dp_{it}), the US bond and equity flow into other countries (eq_{it}), the real exchange rate (ep_{it}), the short-term interest rate (r_{it}), and the economic policy uncertainty index (epu_{it}).[9] We further note that economic policy uncertainty indexes are only available for 21 countries (including the eight countries of the EU). However, these available economic policy

[9] The domestic variables are measured as follows: $y_{it} = \ln(IND_{it} / CPI_{it})$; $dp_{it} = \ln(CPI_{it})$; $eq_{it} = \ln(EQ_{it} / CPI_{it})$; $ep_{it} = \ln(EP_{it} / CPI_{it})$; $epu_{it} = \ln(EPU_{it})$; and $r_{it} = R_{it}$. Where IND is the industrial product index (2010=100), CPI is the consumer price index (2010=100), EQ is the US bond and equity inflow into other countries, EP is the nominal exchange rate per US dollar, R is the short-term interest rate, and EPU is the economic policy uncertainty index.

uncertainty indexes cover almost all key economies in different regions that have played crucial roles in driving the business cycles of the world economy (e.g., the US, the EU area, Japan, the UK, China, Australia etc.).

The country-specific foreign variables (x_{it}^*) can be constructed by fixed or time-varying trade weights corresponding to domestic variables. We prefer using time-varying trade weights to account for the changes in economic linkages among countries and regions over time. Instead, fixed trade weights are used in robustness analysis. Regarding the global variable (d_t), following the standard literature, we add the real global oil price index (p_t^O) in d_t to capture the volatility in the world commodity markets.

We do not impose the same specifications across the country-specific VARX* models. For the US model, all the domestic variables are included as endogenous variables, except for the real exchange rate (ep_{it}) which is determined outside the US model. Given the dominant of the US financial market, we exclude the variables of the equity and bond flows variable (eq_{it}^*) and the short-term interest rate (r_{it}^*) from the US model. In addition, the real oil price variable (p_t^O) is included as an endogenous variable in the US model. This allows the evolution of the global macroeconomic variables to affect the global oil price. For the non-US models, all the domestic variables are included as endogenous variables. In addition, all the foreign variables and the oil price index are included as weakly exogenous variables, except for the real exchange rate (ep_{it}^*).

2.2.2.3. Impulse response functions (IRFs) analysis

The standard IRFs are assumed orthogonal shocks using the Cholesky decomposition of covariance matrix of reduced-form errors. Thus, the IRFs depend on orders of variables, which are often inferred by economic theory. Furthermore, there is no clear empirical identification scheme for uncertainty shock in the current literature (Ludvigson 2016). For these reasons, the IRF approach is not suitable for our GVAR model which consists of a large number of variables. In this paper, we investigate the spillover effects of US economic policy uncertainty shock using the Generalized Impulse Response Functions (GIRFs) proposed by Pesaran and Shin (1998). The GIRFs produce shock response profiles that do not depend on the different orders of variables.

The GIRFs are defined as:

$$GIRF(x_t, u_{\ell t}, n) = E\left(x_{t+n} \mid u_{i\ell t} = \sqrt{\sigma_{ii,\ell\ell}}, I_{t-1}\right) - E\left(x_{t+n} \mid I_{t-1}\right) \qquad (2.12)$$

Where I_{t-1} is the information set at time t-1. $\sigma_{ii,\ell\ell}$ is the diagonal elements of the variance covariance matrix Σ_u corresponding to the ℓ^{th} equation in the i^{th} country at the horizon n. Then GIRF of one unit shock at time t to the ℓ^{th} equation on the j^{th} variable at time t+n is given by the j^{th} element of

$$GIRF(x_t, u_{\ell t}, n) = \frac{e_j A_n G_0^{-1} e'_\ell}{\sqrt{e'_\ell \Sigma_u e_\ell}} \quad n = 0, 1, 2,...; \text{ and } \ell, j = 0, 1, 2,...k \qquad (2.13)$$

Where e_ℓ = (0, 0,…,0, 1, 0,…0) is a selection vector with unity as the ℓ^{th} element as in the case of a specific-country shock. To provide robust inferences, we follow Dees et al. (2007) in using the sieve-bootstrapped medians and confidence bands generated through simulations with 1000 replications in interpreting the spillover effects of US economic policy uncertainty shock.

2.3. Empirical results and discussions

2.3.1. Testing unit root and conintegrations

We first investigate the number of long-run relations based on the augmented Dickey–Fuller test. The empirical results indicate that almost all the variables consist of a unit root in level but are stationary after first- difference. We use the VARX*(2, 1) for almost all countries, as suggested by the Akaike information criterion (AIC). We determine the number of long-run relations of each country-specific VARX* model using Johansen's maximal eigenvalues and trace statistics developed by Pesaran, Shin, & Smith (2000) for models with weakly exogenous I(1) regressors. We select the number of cointegrating relations based on trace test statistics using 95% critical values of MacKinnon (2010).[10]

2.3.2. Testing weak exogeneity

The important assumption of the GVAR model is that foreign variables (x_{it}^*) are weakly exogenous. In other words, there is no feedback from domestic variables (x_{it}) to foreign variables (x_{it}^*). We follow Dees et al. (2007) to test for this assumption, and the empirical results are given in Appendix 2.2. Our empirical results suggest that almost all the foreign variables and the global variable satisfy the weak exogeneity assumption.

[10] The details of the lag selection and cointegration tests are available on request.

2.3.3. The spillover effects of US EPU shock on the global economy

We now turn to the spillover effects of US economic policy uncertainty shock on the global economy. In particular, we consider the responses of different countries to a one standard error positive shock to US economic policy uncertainty. Our GVAR model consists of the large empirical results of the 24 different countries and the EU area (including eight countries). Therefore, we will briefly discuss the main features of the empirical results and then select some typical countries for the illustration purposes.[11] Furthermore, due to the data constraints for some countries, we are unable to present empirical results where the selected countries are completely consistent across figures. However, we ensure that the selected countries are consistent as much as possible and representative for different regions.

We first examine the spillover effects of US economic policy uncertainty shock on the output of other economies in Figure 2.1. We first confirm the robustness of our GVAR model by looking at the US economy. The response of the real output is estimated to be negative for a period of more than 6 months. However, this effect is small and reaches its lowest level after around two months later. Our finding here is highly consistent with to the "wait-and-see" effect channel, which is widely confirmed in the case of the US economy (e.g., Baker, Bloom, and Davis 2016; Nicholas Bloom 2009; Jurado, Ludvigson, and Ng 2015). Furthermore, as shown below, US economic policy uncertainty shock can lead to the depreciation of US dollar against other currencies. As a result, the costs of imported raw materials

[11] The detail of the empirical results of all the countries and region is available on request

are increased and this leads to lowering the level of investment and thereby output.

Insert Figure 2.1 here

We now move on the spillover effects on the real output of other economies. Overall, we figure out that US economic policy uncertainty shock has the significant spillover effects on the output of other economies. However, the spillover effects are also small and heterogeneous across countries. We outline some features of the empirical results as follows. First, the spillover effects of US economic policy uncertainty shock are not negative for all, as highlighted by the previous studies. For almost all economies, their output first increases about one month after US economic policy uncertainty shock and only declines later after about two to four months (e.g., Brazil, Canada, the EU, Chile, Korea, Malaysia, Japan, Norway, Sweden, and the UK). Second, for some economies, their output declines contemporarily after US economic policy uncertainty shock. This is the case in two large trading partners with the US—China and Mexico. This result implies that trade is a crucial transmission channel of US economic policy uncertainty shock. This argument is clearly proven in the next section (see Figure 2.11) in which we find that economies with the higher trade shares with the US are exposed be more vulnerable to US economic policy uncertainty shock. Third, we stress that almost all economies are found to be more vulnerable than the domestic economy (the US) to US economic policy uncertainty shock.

US economic policy uncertainty shock can affect the output of other economies through various channels. The first is the "wait-and-see" effect channel, which is confirmed by Carrière-Swallow and Céspedes (2013) and Trung (2019). In addition, US economic policy uncertainty shock can also lower the US demands for investment and consumption. For this reason, US EPU shock can influence the output of other economies via exports that is damped in response to US EPU shock. We will provide some extra spillover channels below.

We now turn to the bond and equity flows in Figure 2.2. In general, we find mixed results. For some economies, the capital inflows decrease significantly following US economic policy uncertainty shock (e.g., Brazil, Canada, Indonesia, Mexico, Turkey, and Argentina etc.). This result is consistent with the "flight to safety" behaviour type documented in the current literature. In other words, US economic policy uncertainty shock involves risks (Bloom, 2014), and this declines the capital flows into emerging countries which are considered as "less safe" markets Gauvin, McLoughlin, and Reinhardt 2014).

Insert Figure 2.2 here

On the contrary, US economic policy uncertainty shock also hinders the growth prospect of the US economy and thereby forces investors to switch their capital flows to other potential markets. For this reason, the capital flows into some economies are found to increase immediately after US economic policy uncertainty shock but then slightly decline later (e.g., Japan, China, Korea and the euro area). Combining Figure 2.1 and Figure 2.2 shows that following US economic policy uncertainty shock, the decreases (increases) in the output of other economies are highly coincidental with the falls (increases) in the capital inflows. Our finding here is almost significant for all economies. Therefore, the capital inflows are a key transmission channel of US economic policy uncertainty shock.

We now examine the exchange rate markets in Figure 2.3. In general, we again find mixed results. Theoretically, an increase in US economic policy uncertainty can induce the depreciation of the US dollar against other currencies because of the reduction in the demands for holding US currency. This theory is significant in a few economies, such as Japan, Malaysia, Saudi Arabia, Thailand, China, the UK, and Switzerland. However, this effect is very small.

On the contrary, for other economies, US economic policy uncertainty shock results in the currency depreciation. These results here can be accounted for by two reasons. First, the currency depreciation (appreciation) can be stemmed from the capital outflows (capital inflows), as shown in Figure 2.2 above. Our discussion here almost fits to all economies in our model. Second, for a few economies, they experience the currency depreciation although capital inflows. However, as noted by Mueller, Tahbaz-Salehi, and Vedolin (2017), US economic policy uncertainty shock can induce higher excess returns for other currencies and therefore encourage financiers to increase trading. Consequently, this triggers the depreciation of other currencies against the US dollar in the short run. This argument fits to some advanced economies (e.g., the EU, the UK, Australia, Sweden, Norway etc.).

Insert Figure 2.3 here

We now examine the spillover effects on the price index in Figure 2.4. We highlight some key features of the empirical results as follows. First, for almost all economies, we figure out that the price index first increases somewhat after US economic policy uncertainty shock but then decline later. This result is contrary to the previous studies which found a fall in the price index following US economic policy uncertainty shock (Han, Qi, and Yin 2016; Kamber et al. 2016). Our finding here, however, is more plausible because the increased price index could stem from increasing the "hot capital inflows", as exposed in Figure 2.2, or from raising the prices of imported raw materials caused by the currency depreciation, as shown in Figure 2.3. These arguments here are almost significant for all economies in our model.

Insert Figure 2.4 here

For other economies, we reveal a decline in the price index following US economic policy uncertainty shock. This is the case in a few economies, such as Australia, Canada, Chile, the EU, India, Philippines, the UK, and the US. This decline reaches the lowest level after about two or three months, which coincides with the period of the largest fall in the output following US economic policy uncertainty shock. However, this drop is also very small.

Finally, regarding the short-term interest rate, US economic policy uncertainty shock can lead to the stagnation of the economy. For this reason, our model predicts that central banks of both emerging and advanced economies tend to reduce their short-term interest rate in order to stabilize the economy. This result is found significantly in almost all economies. For some other economies, the short-term interest rate first increases but then significantly declines later, after about two to three months. However, this increase is only significant for a few economies, such as Brazil, Chile, Mexico, Thailand, and Indonesia. One possible explanation for this result is that the monetary policy authorities try, in an attempt, to prevent the capital outflows, the currency depreciation, and small inflation due to US economic policy uncertainty shock, as exposed above. We also note that the spillover effects on the short-term interest rate are also small.[12]

Before closing this section, we examine how important is U.S economic policy uncertainty shock? To answer this question, we examine the generalized forecast error variance decompositions (GFEVDs) of the considered variables. We first underline that the contribution of US economic policy uncertainty shock in explaining the short-run fluctuation of the considered variables is quite small. Second, the output, capital inflows and inflation are estimated to respond more strongly to US EPU shock than other variables. Finally, the contribution of US EPU shock is heterogeneous across countries. For example, US economic policy uncertainty shock interprets more fluctuation of output in Brazil, the euro area, India, Korea, Malaysia, and UK than in other economies. The all results of the GFEVDs are presented in Appendix 2.3.

2.3.4. Robustness Analysis

We present some robustness analyses as follows. First, we now re-estimate the GVAR model using fixed trade weights of the 2006–2008 period and using another US uncertainty index – named as the macroeconomic uncertainty index – proposed by Jurado, Ludvigson, and Ng (2015). All robustness analyses, presented in Appendix 2.4, reconfirm that our GVAR model is consistent.

2.4. Further investigations

In the previous section, we also found that the spillover effects of US EPU shock are heterogeneous across countries. The responses of both real and financial variables in other economies are estimated to be both positive and negative after

[12] The empirical results of the short-term interest rate are available on request.

US EPU shock. In addition, some economies experience larger spillovers than others. In this section, we attempt to grasp the important question of what factors account for the different spillovers across countries.

2.4.1. The structure of US economic policy uncertainty shock: Monetary Policy Uncertainty vs. Fiscal Policy Uncertainty

The heterogeneous spillovers of US economic policy uncertainty across countries can be attributed to the different structures of US economic policy uncertainty shock. In other words, the different types of US economic policy uncertainty shock will generate different spillover outcomes (Gabauer and Gupta 2018; Mumtaz and Surico 2018). For this reason, a recently growing strand of the literature has grasped the effects of the different types of policy uncertainty shock on economic activities, for instance, monetary policy uncertainty (Creal and Wu 2017; Fernández-Villaverde et al. 2011a; Herro and Murray 2013; Husted, Rogers, and Sun 2017; Kurov and Stan 2018; Mumtaz and Zanetti 2013; Sinha 2016a) and fiscal policy uncertainty (Born and Pfeifer 2014; Fernández-Villaverde et al. 2015; Johannsen 2014; Mumtaz and Surico 2018; Richter and Throckmorton 2015). However, these studies mainly focused on a country perspective while few studies have dealt with the international spillover effects.

Gabauer and Gupta (2018) shown that monetary and fiscal policy uncertainty are the two most dominant sources of US economic policy uncertainty shock. Therefore, in this section, we advance this literature by examining an interesting question: How are the spillover effects of US monetary policy uncertainty and fiscal policy uncertainty shock? These findings are important for not only partly explaining why the spillover effects are heterogeneous across countries but also for offering the new insights into policy interventions.

In the GVAR model specification, we impose both US monetary policy uncertainty and US fiscal policy uncertainty index in the global variable (d_t). However, we do not impose the same specifications for all economies. For the non-US models, both of them are included as weakly exogenous variables. By contrast, for the US model, they are included as endogenous variables, together with aggregate US economic policy uncertainty index. This specification takes two benefits. First, this allows the domestically macroeconomic conditions (the US) to drive both US monetary and fiscal policy uncertainty shock. Second, this allows both US monetary and fiscal policy uncertainty shock to be transmitted globally, while controlling for other specific US economic policy uncertainty shock, such as US political and regulatory uncertainty shocks etc.

We use the US monetary policy index, proposed by Husted, Rogers, and Sun (2017). They measure monetary policy uncertainty index using the same methodology –newspaper coverage – proposed by Baker, Bloom, and Davis (2016). In particular, they search for articles containing the triple of (i) "uncertainty" or "uncertain," (ii)"monetary policy(ies)" or "interest rate(s)" or "Federal fund(s) rate" or "Fed fund(s) rate," and (iii) "Federal Reserve" or "the Fed" or "Federal Open Market Committee" or "FOMC", daily published in the Washington Post, Wall Street Journal, and New York Times (Husted, Rogers, and Sun 2017). Baker, Bloom, and Davis (2016) provide the same measurement for monetary policy uncertainty. However, we prefer the index of Husted, Rogers, and Sun (2017) for three reasons. First, to account for the changing volume of total news articles, they first divide the raw count of identified articles by the total number of news articles mentioning "Federal Reserve", or more precisely, any of the words in category (iii), for each newspaper in a given period. This scaling choice also helps address issues related to time-varying popularity and increased coverage of the Fed due to improved transparency in its communication strategy (Husted, Rogers, and Sun 2017). Second, they restrict attention to the Wall Street Journal, New York Times and Washington post – which likely devote more coverage to esoteric monetary policy matters (quantitative easing, forward guidance, etc.) than the broader set of newspapers that Baker, Bloom, and Davis (2016) consider. Finally, they quantify uncertainty about U.S. monetary policy while Baker, Bloom, and Davis (2016) quantify concerns monetary policy uncertainty in the United States, regardless of whether those concerns involve U.S. or foreign monetary policy[13].

For fiscal policy, we use the US fiscal policy uncertainty index, developed by Baker, Bloom, and Davis (2016). Baker, Bloom, and Davis (2016) construct the fiscal policy uncertainty index using the newspaper coverage. The fiscal policy uncertainty index has to first fulfil the requirements as the economic policy uncertainty measurement, but also contain the terms related to fiscal policy such as: government spending, federal budget, budget battle, balanced budget, defense spending, military spending, entitlement spending, fiscal stimulus, budget deficit,

[13] The data of US monetary policy uncertainty can access at: http://www.policyuncertainty.com/monetary.html.

federal debt, national debt, Gramm-Rudman, debt ceiling, fiscal footing, government deficits, balance the budget[14].

2.4.1.1. The spillover effects of US monetary policy uncertainty

We first look at the spillover effects of US monetary policy uncertainty shock on the output in Figure 2.5. For the US economy, the response of the output is estimated to be negative for a period of about two month after US monetary policy uncertainty shock. This is in line with the current literature (Husted et al., 2017).

Insert Figure 2.5 here

Our interest is the spillover effects of US monetary policy uncertainty shock on other economies. In general, we find a negative response of the output of other economies after US monetary policy uncertainty shock. This effect is significant for almost all economies, except for only a few economies, such as the UK, China, and India. In addition, almost all economies are found to be more vulnerable than domestic economy (the US) following US monetary policy uncertainty shock. This finding underlines the importance of US monetary policy in driving the business cycles of the global economy. In comparison to the aggregate US economic policy uncertainty shock above, the spillover effects of US monetary policy uncertainty on the output are now almost all negative and more consistent across countries. Furthermore, the spillover effects are now more contemporary but quickly rebound after about two months.

[14] The data of US fiscal policy uncertainty can access at: http://www.policyuncertainty.com/categorical_epu.html.

As exposed in the previous section, the capital flows are a key transmission channel of US economic policy uncertainty shock. We, therefore, examine whether the capital inflows can account for falls in the output in Figure 2.5 above. The empirical results of the capital flows into other economies are depicted in Figure 2.6. We find that the capital flows into other economies decline immediately after US monetary policy uncertainty shock. This is significant for almost all economies, except for only a few countries, such as Mexico, Malaysia, Norway, and Turkey. Our result here is also consistent with the "flight to safety" behavior type above. This finding also partly explains why we find a fall in the output of other economies after US monetary policy uncertainty shock in Figure 5. In comparison with the aggregate US economic policy uncertainty shock, we find that the spillover effects of the US monetary policy uncertainty shock on the capital flows are now obviously negative and consistent across countries. In addition, the magnitude of the spillover effects is now estimated to be larger and more contemporary.

Insert Figure 2.6 here

Finally, by declining the capital inflows, US monetary policy uncertainty shock triggers the currency depreciation and deflation for almost all economies. As a result, this forces the central banks of other economies to lower the short-term interest rate in order to stabilize the economy. However, we further note that all these spillover effects are also very small as expose in the previous section.[15]

[15] The details of the empirical results of the exchange rate, the price index, and the short-term interest rate are available on request.

2.4.1.2. The spillover effects of US fiscal policy uncertainty

We first look at the spillover effects of US fiscal policy uncertainty shock on the output in Figure 2.7. Unlike US monetary policy uncertainty shock, the responses of the output are now estimated to be negative for only a few countries, such as China, Mexico. On the contrary, for almost all economies, the output first significantly increases but then declines later, after about three to four months. Our findings here show the different spillover effects between US monetary and fiscal policy uncertainty shock. As a result, aggregate US economic policy uncertainty shock, containing both monetary policy uncertainty and fiscal policy uncertainty shock, provides the ambiguous and heterogeneous spillover effects that we exposed in the previous section.

Insert Figure 2.7 here

We move on to the capital flows in Figure 2.8. More interestingly, we find that US fiscal policy uncertainty shock drops capital inflows for only a few countries (e.g., Malaysia and Mexico), whereas capital inflows significantly increase in almost all other economies. For this reason, we find the positive spillover effects of US fiscal policy uncertainty shock on the output for almost all economies in Figure 2.7.

Insert Figure 2.8 here

As noted by Mumtaz and Surico (2018), US fiscal policy uncertainty shocks hinder the growth prospect of the domestic economy because they reduce the consumption and business confidence. These effects are larger and more persistent than monetary policy uncertainty shocks. Furthermore, Mumtaz and Surico (2018) remarked that investors and households are more sensitive to US fiscal policy uncertainty shock, especially regarding the government debt issues because of increasing the probability of the government default. For these reasons above, investors are willing to shift their investments from the US economy to other countries under US fiscal policy uncertainty shock. This explains why we find an increase in the capital flows into other economies after US fiscal policy uncertainty shock.

Finally, by surging the capital inflows, US monetary policy uncertainty shock triggers the currency appreciation for almost all economies in short-run. As a result, the price index and the short-term interest rate first increase but then declines later, after around two to three months. However, we again note that all these spillover effects are also very small as exposed in the previous section.[16]

2.4.2. The role of the receiving country's characteristics

A number of recent contributions has shown growing interest in examining the structure of business cycles and the transmission channels of external shocks in an open economy. This literature has emphasized the roles of the specific country's characteristics in transmitting external shocks, such as level of development, financial and trade openness, and institutions.

Trade openness can exacerbate the vulnerability of the domestic economy to external shocks because exports, which are dampened due to external shocks, account for a large share of the domestic output (Calderón and Schmidt-Hebbel 2008; Georgiadis 2016; Giovanni and Levchenko 2009; Kose, Prasad, and Terrones 2003; Sakyi, Villaverde, and Maza 2015). On the other hand, some authors suggest

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[16] The details of the empirical results of the exchange rate, the price index, and the short-term interest rate are available on request.

that trade openness can diminish the exposure to external shocks by promoting risk diversifications (Calderón and Schmidt-Hebbel 2008; Cavallo and Frankel 2008; Down 2007).

Financial openness can theoretically amplify the adverse effects of external shocks by allowing external financial shocks to be transmitted more promptly across borders (Mishkin 2006), or by leading to a sudden collapse of capital flows (Aghion, Bacchetta, and Banerjee 2004; Stiglitz 2000). On the contrary, some authors argued that financial openness can help the domestic economy less vulnerable to external shocks by improving risk-sharing possibilities (Buch and Yener 2010; Kose, Prasad, and Terrones 2003; Obstfeld and Rogoff 2000) or by strengthening the stability of the domestic financial system (Gossel and Biekpe 2013; Mishkin 2009; Williamson 2003).

Finally, few studies have found the crucial role of institutions in promoting the resilience of the domestic economy after external shocks (Acemoglu et al. 2003; Briguglio et al. 2009; Raddatz 2007). Broner and Rigobon (2005) further noted that weak institutions induce more volatility in capital flows and thereby increase the macroeconomic fluctuations in the domestic economy after external shocks.

In this section, we proceed to examine the receiving country's characteristics in determining the spillovers of US economic policy uncertainty shock. In particular, we intend to compare the magnitude of the spillover effects of US economic policy uncertainty shock with respect to level of development, financial and trade openness, and quality of institutions. For each measure of the receiving country's characteristics, we split the receiving countries in our sample into two sub-groups: (i) the countries for which the mean value, taken over the sample period, is above the cross-country median and (ii) the countries for which the mean value is below the median. Appendix 2.5 provides the details of the specific receiving countries' characteristics, measurements, and resources, and Appendix 2.6 shows the classifications of the two sub-groups of the receiving countries.

2.4.2.1. Emerging economies versus advanced economies

Figure 2.9 compares the magnitude of the spillover effects on the different levels of development and regions. We expose that developing and emerging economies are found to be more vulnerable than advanced economies following US economic policy uncertainty shock.

Insert Figure 2.9 here

In the comparison among regions, we discover that the Asian emerging economies are more susceptible to US economic policy uncertainty shock. This finding is not surprising because of the higher trade shares of this region with the US economy. These findings suggest that developing and emerging economies, especially in the Asian region, need to pay more attention to US economic policy uncertainty shock in governing their economies.

2.4.2.2. High financial openness versus Low financial openness

We proceed to examine the role of financial openness in Figure 2.10. We reveal that economies with higher financial openness have less exposure to US economic policy uncertainty shock. Our finding, therefore, underlines the vital role of financial openness in mitigating adverse shocks by increasing risk-diversification or firmly strengthening the stability of the domestic financial system (Gossel and Biekpe 2013; Mishkin 2009; Williamson 2003). Furthermore, as noted by Carrière-Swallow and Céspedes (2013), the adverse effects of US uncertainty can be amplified in the presence of financial constraints. Financial openness can thereby reduce the adverse effects of US economic policy uncertainty shock by increasing access to external finance and reaping collateral benefits from the global financial markets.

Insert Figure 2.10 here

2.4.2.3. High trade openness versus Low trade openness

We now move on the role of trade openness in Figure 2.11. We remark that economies with higher trade shares with the US economy suffered much more severely than others due to US EPU shock. This result is not surprising because US economic policy uncertainty shock leads to drops in the domestic demands for investment and consumption (Nicholas Bloom 2009; Jurado, Ludvigson, and Ng 2015). Therefore, the more economies trade with the US, the more susceptible they are to US economic policy uncertainty shock. This result further implies that trade is an important transmission channel of US economic policy uncertainty shock.

Insert Figure 2.11 here

We now turn to trade openness with the world to account for the diversifications. Interestingly, we find contrary results. By increasing the risk-sharing possibilities, diversified trade openness can help countries to mitigate the adverse impacts of US economic policy uncertainty shock. Our findings partly resolve the current debate about the relationship between trade openness and the vulnerability of the domestic economy. We stress that trade openness can reduce the adverse effects on the domestic economy when trade openness is diversified.

2.4.2.4. Good institutional quality versus Bad institutional quality

We proceed to grasp the role of institutions in Figure 2.12. Our empirical results figure out that economies with better institutional quality are less vulnerable to US economic policy uncertainty shock. North (1990) interpreted that effective institutions may create appropriate motivations, or reduce transaction costs, thereby encouraging individuals to engage in productive investments. In addition, efficient institutions can mitigate the macroeconomic fluctuations in the domestic economies after external shocks by reducing the volatilities in the capital flows Broner and Rigobon (2005). For these reasons, improving the quality of institutions, therefore, not only promote the long-run economic growth (Bosworth and Collins 2003; Hall and Jones 1999; Rodrik, Subramanian, and Trebbi 2004) but also increase the resilience of the domestic economy to external shocks (Acemoglu et al. 2003; Briguglio et al. 2009; Raddatz 2007).

Insert Figure 2.12 here

2.5. Conclusions and policy implications

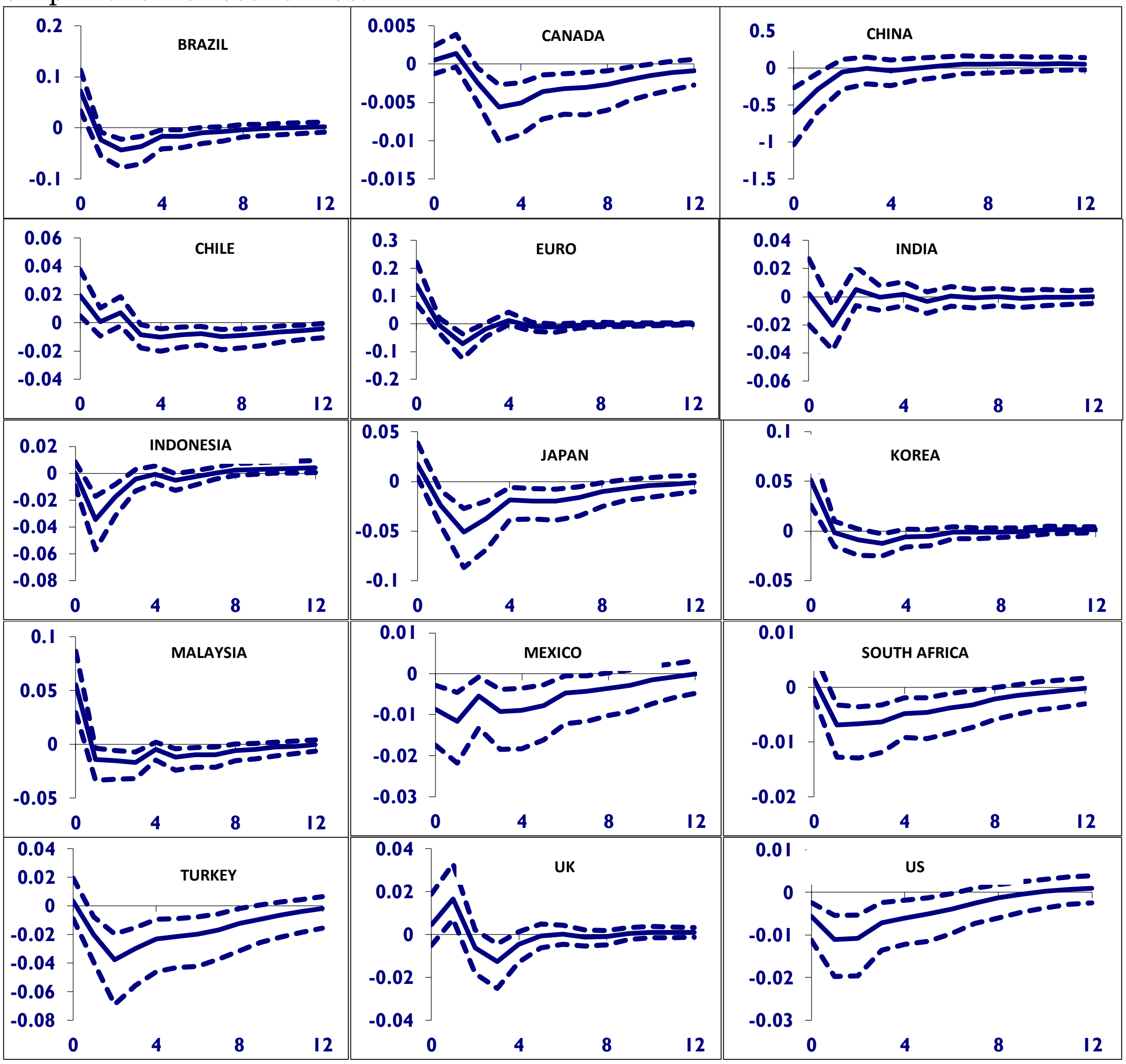
The article investigates the spillover effects of US economic policy uncertainty shock on the global economy. We find that US economic policy uncertainty shocks are significant in driving the business cycle fluctuations of the global economies. However, the spillover effects are heterogeneous across economies, which can be attributed to the different types of US economic policy uncertainty shock (monetary policy uncertainty vs. fiscal policy uncertainty) and the specific receiving country's characteristics (level of development, trade and financial openness, and quality of institutions).

The empirical results open some important questions and implications. The spillover effects of US economic policy uncertainty shock are not negative for all, at least under the certain economic characteristics and structures. Therefore, how do we theoretically understand the role of the specific country's characteristics (e.g., financial and trade openness, institutions etc.) in transmitting uncertainty shock? How do they interact with other channels (e.g., the "wait-and-see", risk premium") in determining the effects of uncertainty on the economy? Second, we shown that the different types of uncertainty will generate the different spillover outcomes. Therefore, future research need to examine the different types of uncertainty. This is important for both theoretical understandings and policy interventions.

The empirical results of the article further offer some crucial policy implications for both advanced and emerging economies. First, clearly, trade openness can help a country to grow faster. However, the strategy of trade openness should be diversified. This can assist countries to get the economic benefits of trade openness while minimizing their vulnerability to US economic policy uncertainty shocks. Second, advanced and emerging economies need to increase financial openness through increasing efficient financial regulations and financial market transparency. This can help them to not only increase their access to external finance for long-run economic growth but also to stabilize the economy by reducing the volatility of international capital flows due to US economic policy uncertainty shock. Finally, all economies should put more effort into improving the quality of institutions in terms of political stability, transparency, getting rid of corruption, macroeconomic policy management, accountability, and efficient regulations. This can incentivize individuals to engage in productive investments and to stabilize the volatility of international capital flows, thus mitigating the adverse effects of US economic policy uncertainty shock.

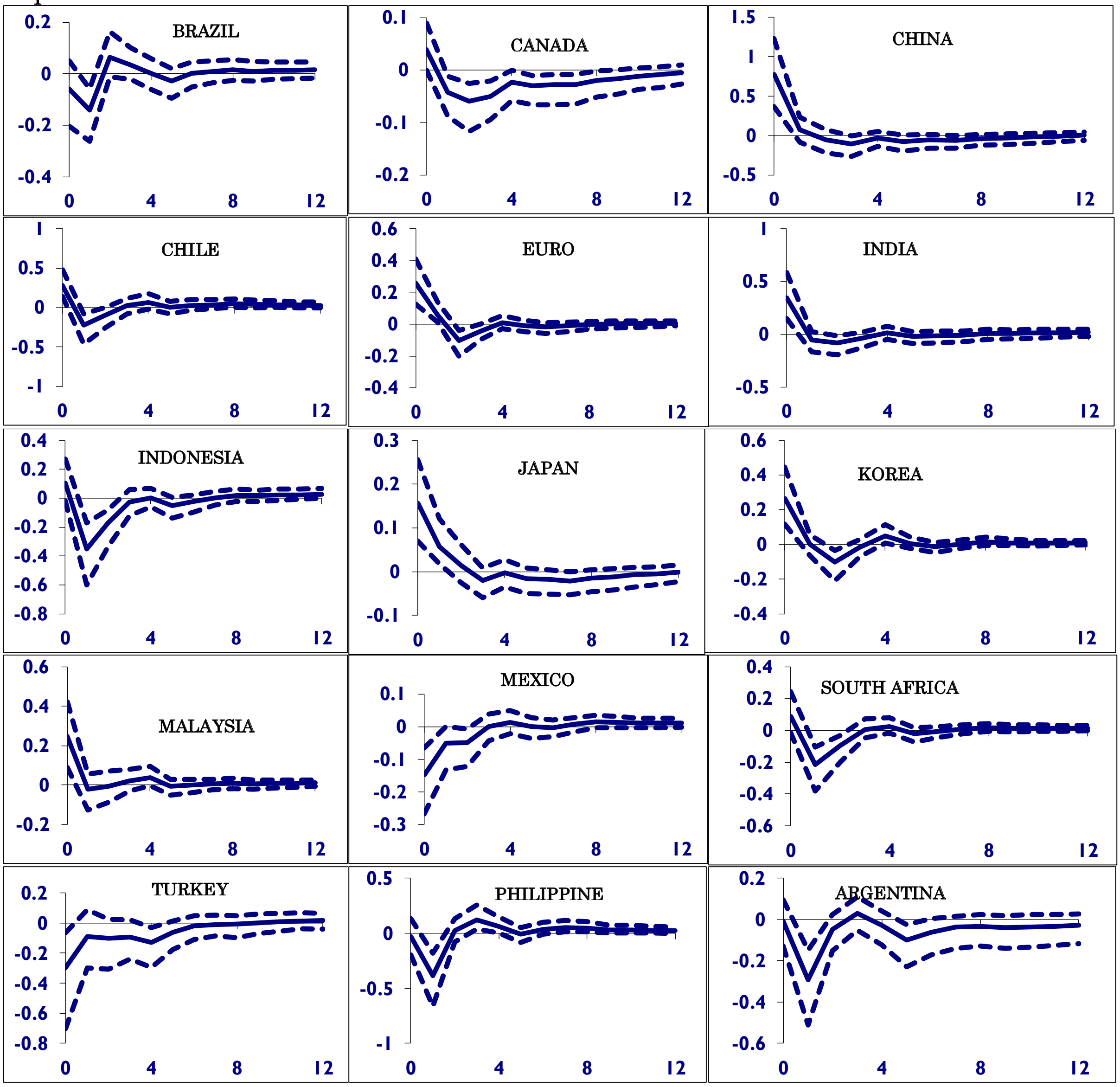
Tables and Figures

Figure 2.1. The spillover effects of US economic policy uncertainty shock on the output of other economies.



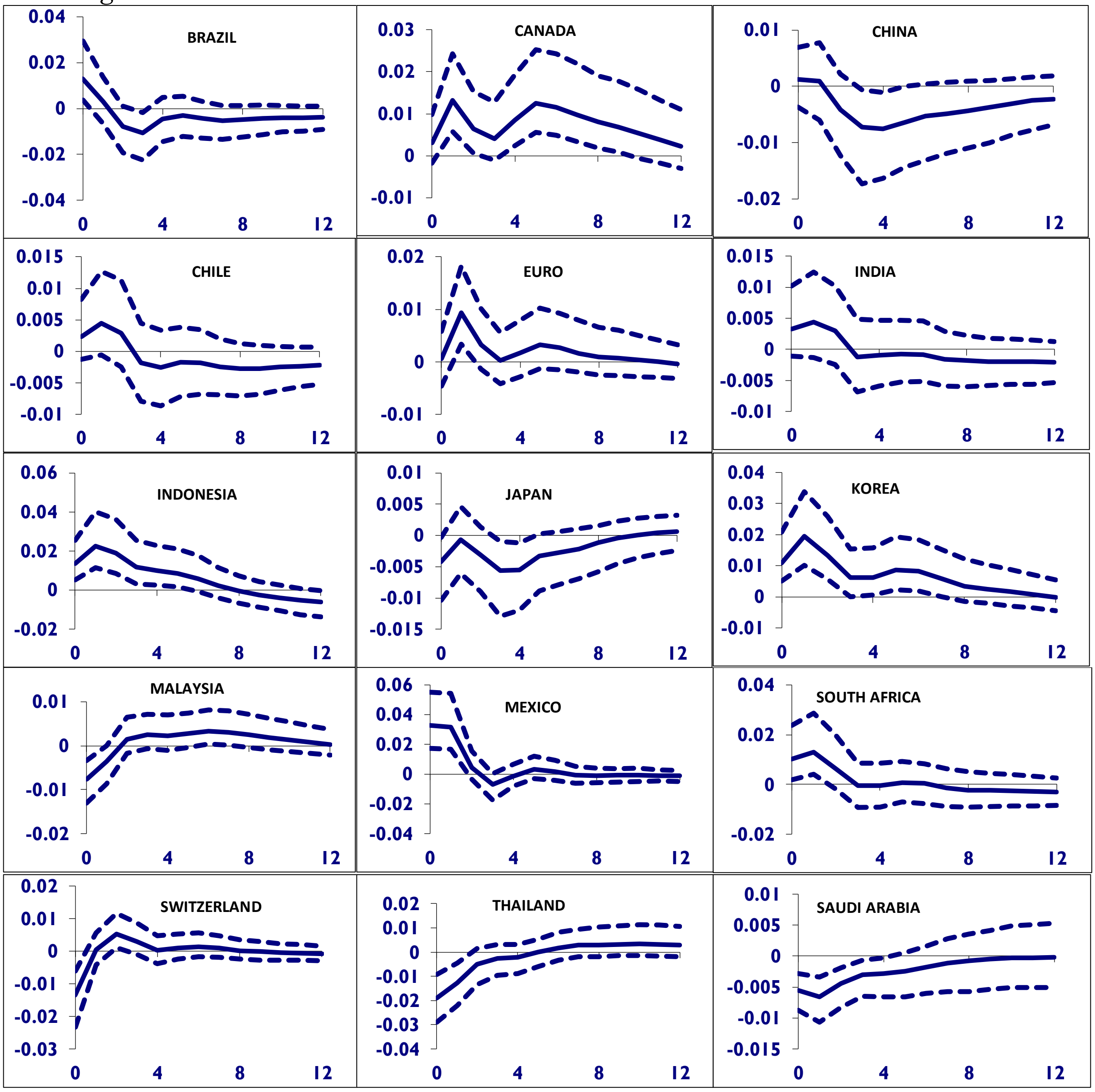
Note: bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months, and the vertical axes identify percent.

Figure 2.2. The spillover effects of US economic policy uncertainty shock on the capital flows into other economies.



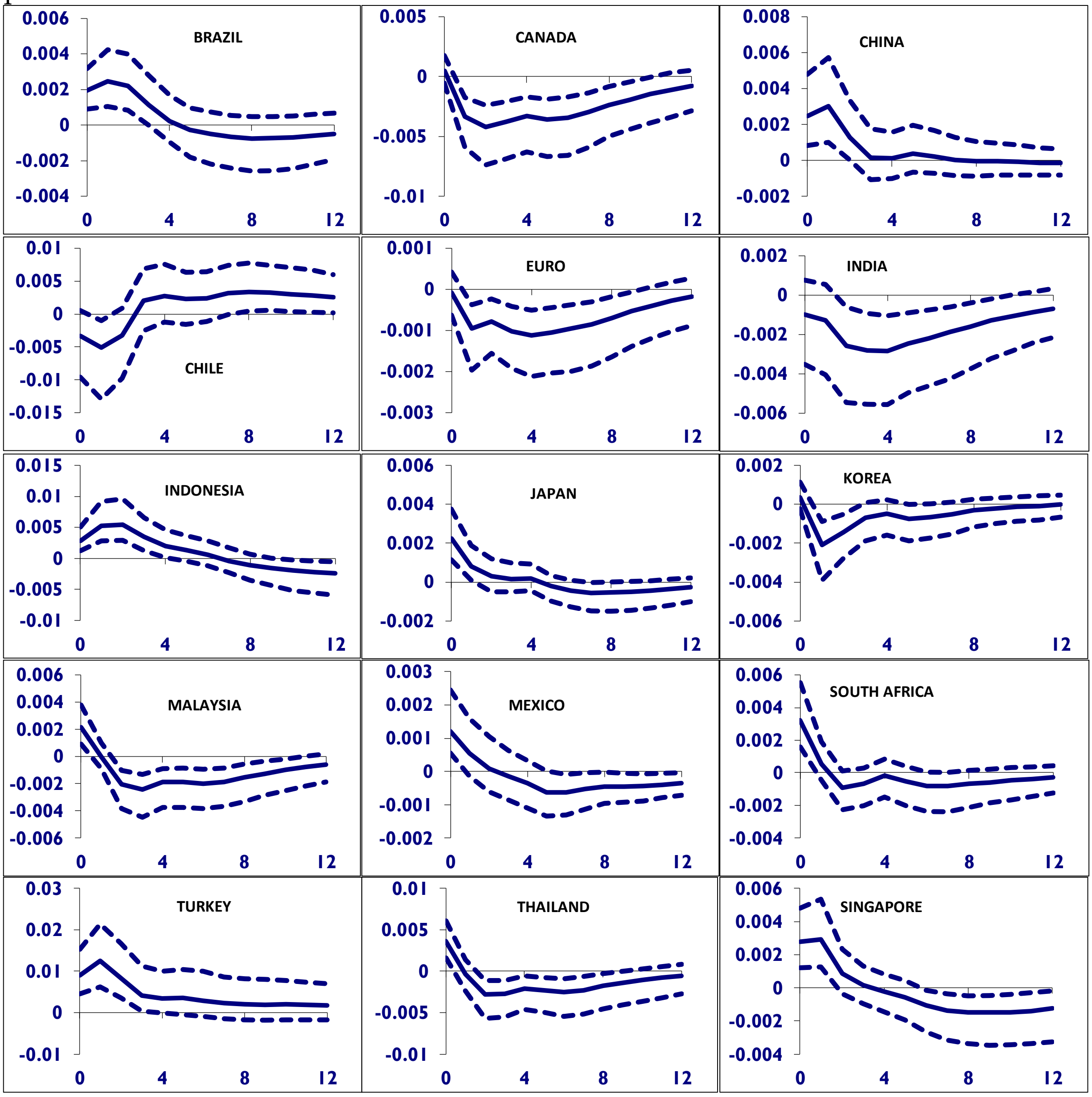
Note: bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months, and the vertical axes identify percent.

Figure 2.3. The spillover effects of US economic policy uncertainty shock on the exchange rate of other economies.



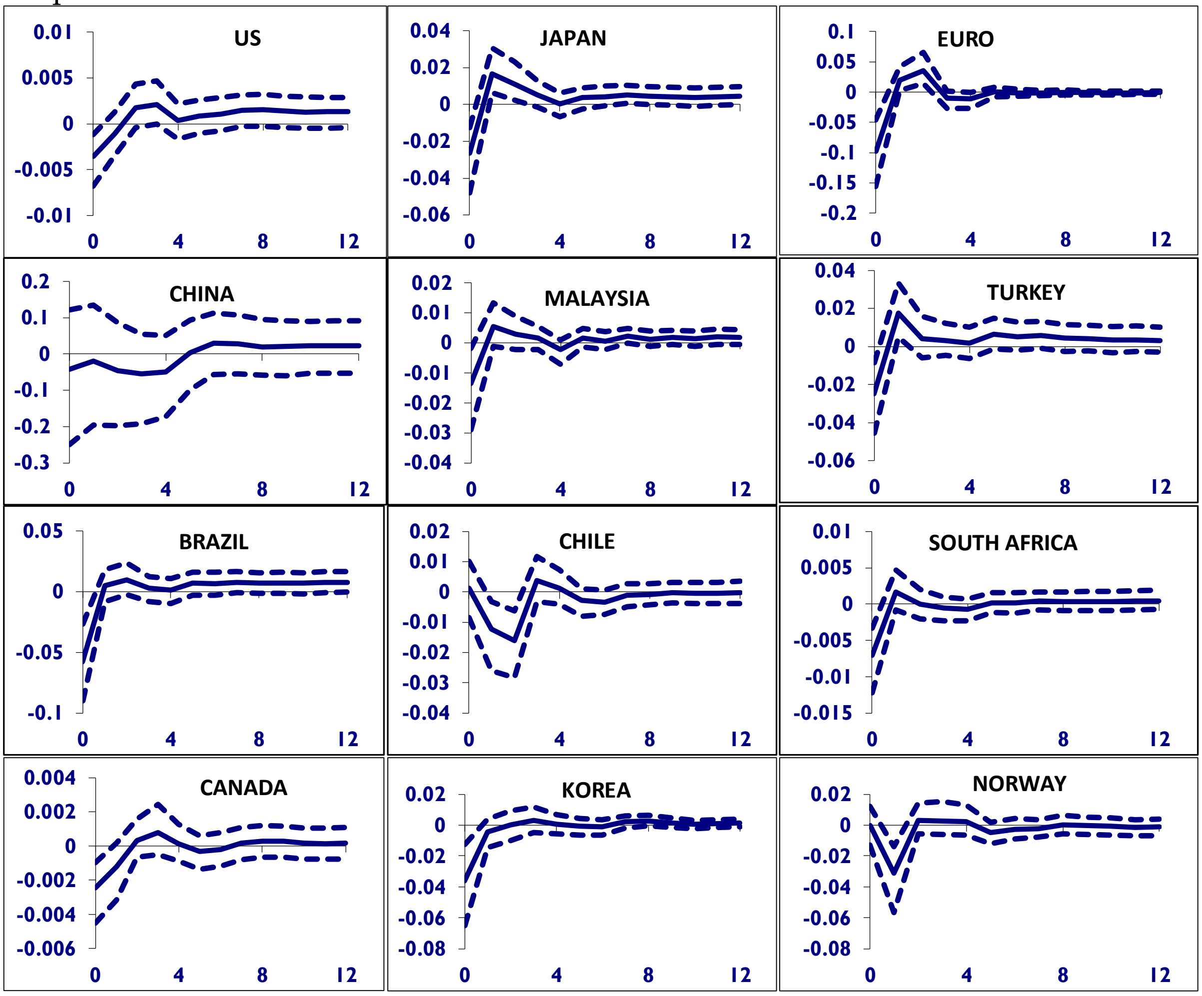
Note: bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months, and the vertical axes identify percent.

Figure 2.4. The spillover effects of US economic policy uncertainty shock on the price index of other economies.



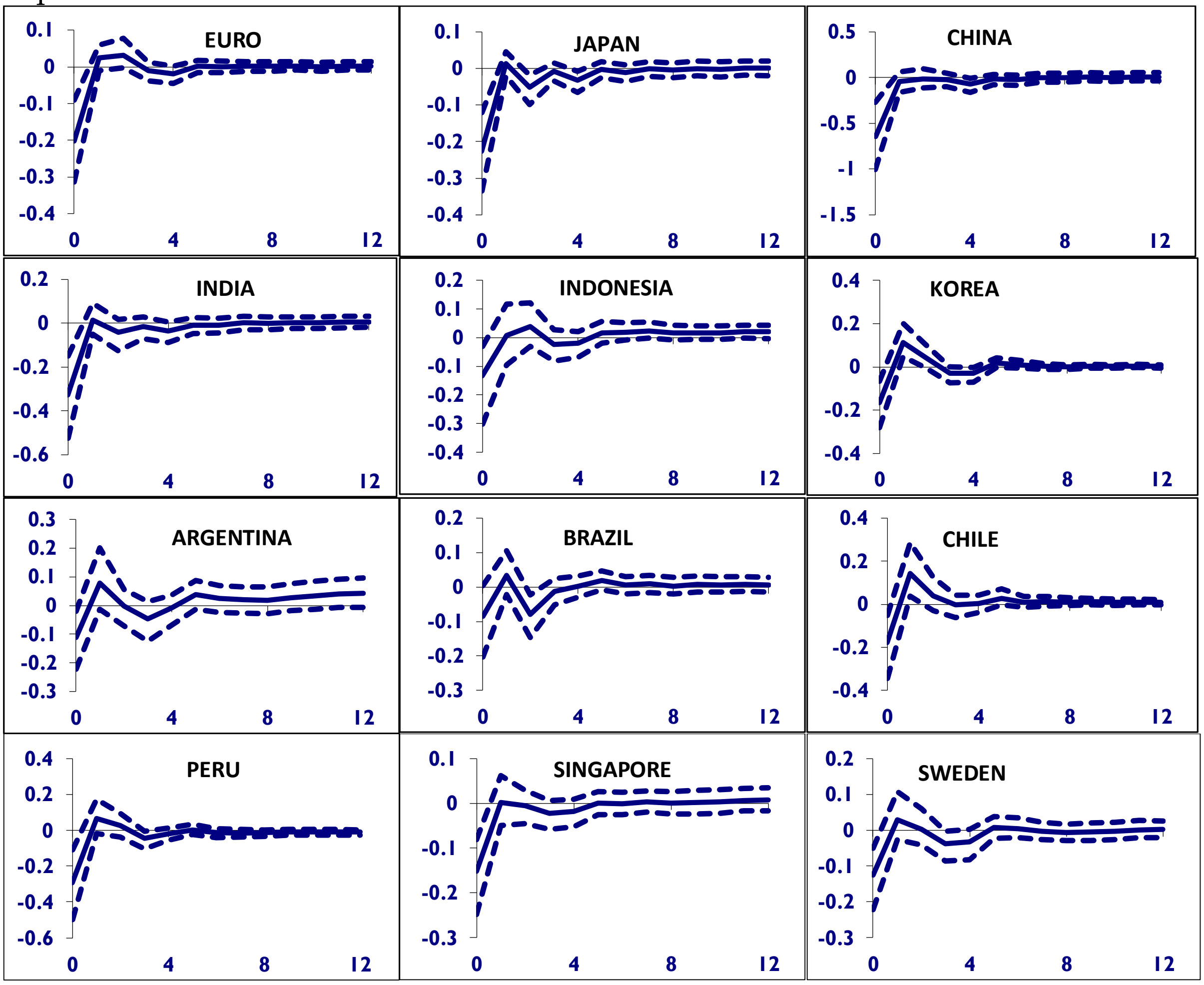
Note: bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months, and the vertical axes identify percent.

Figure 2.5. The spillover effects of US monetary policy uncertainty shock on the output of other economies.



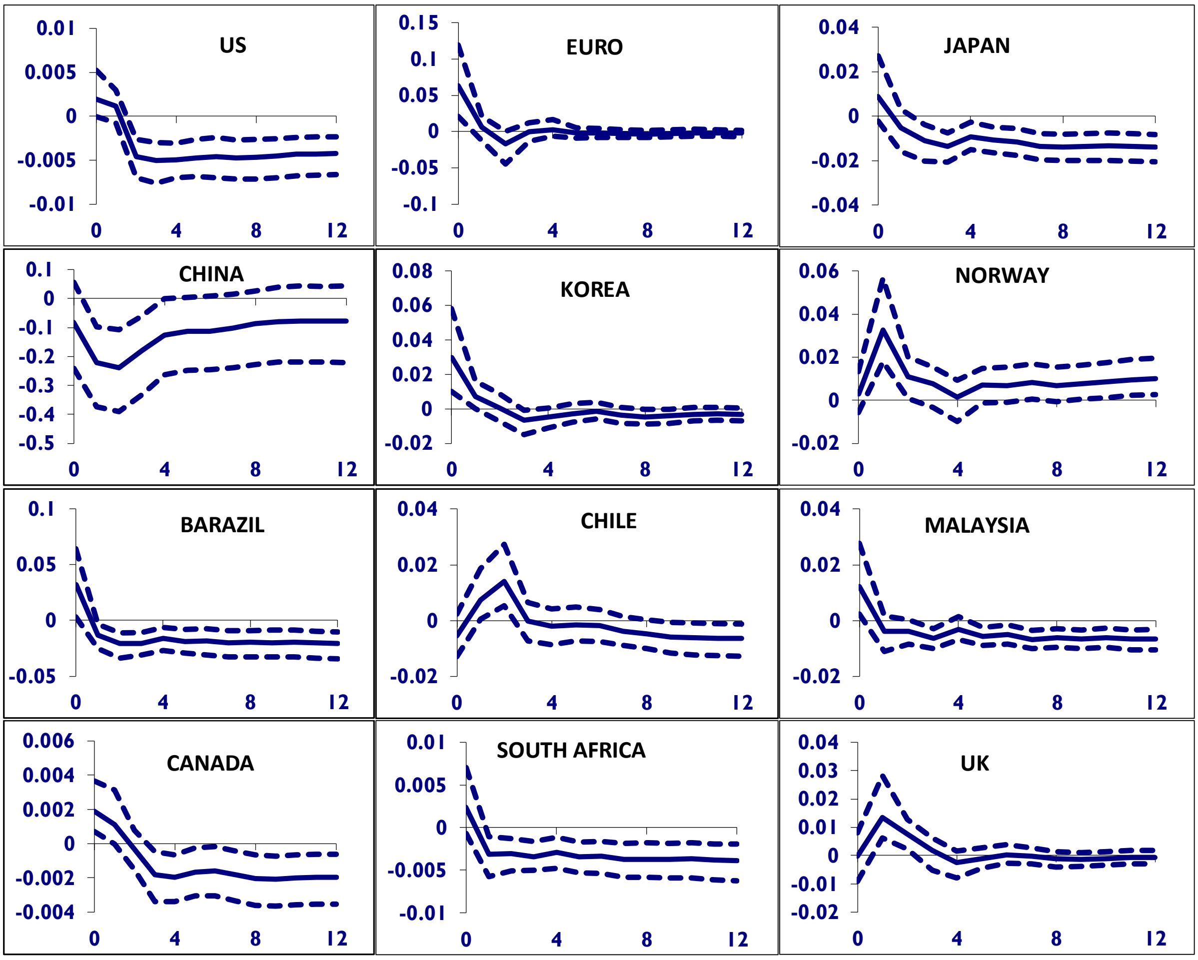
Note: the bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months, and the vertical axes identify percent.

Figure 2.6. The spillover effects of US monetary policy uncertainty shock on the capital flows into other economies.



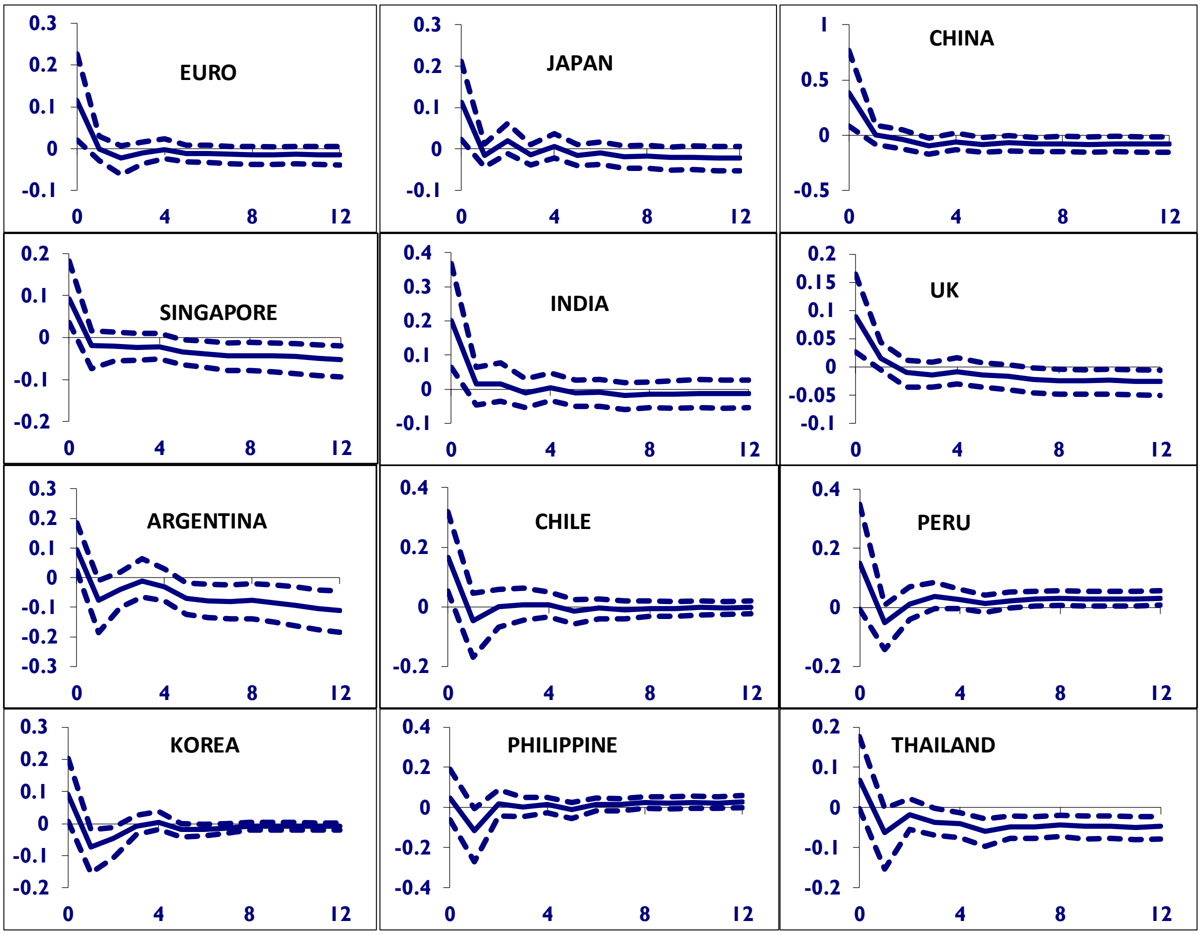
Note: the bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months, and the vertical axes identify percent.

Figure 2.7. The spillover effects of US fiscal policy uncertainty shock on the output of other economies.



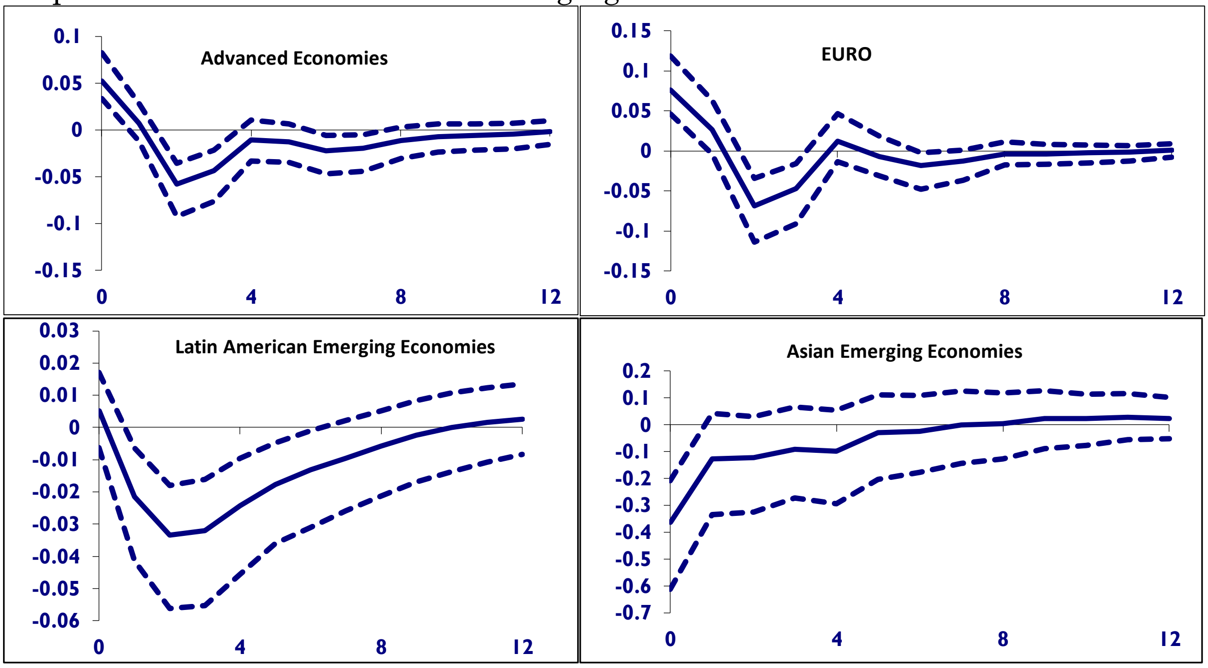
Note: the bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months, and the vertical axes identify percent.

Figure 2.8. The spillover effects of US fiscal policy uncertainty shock on the capital inflows into other economies.



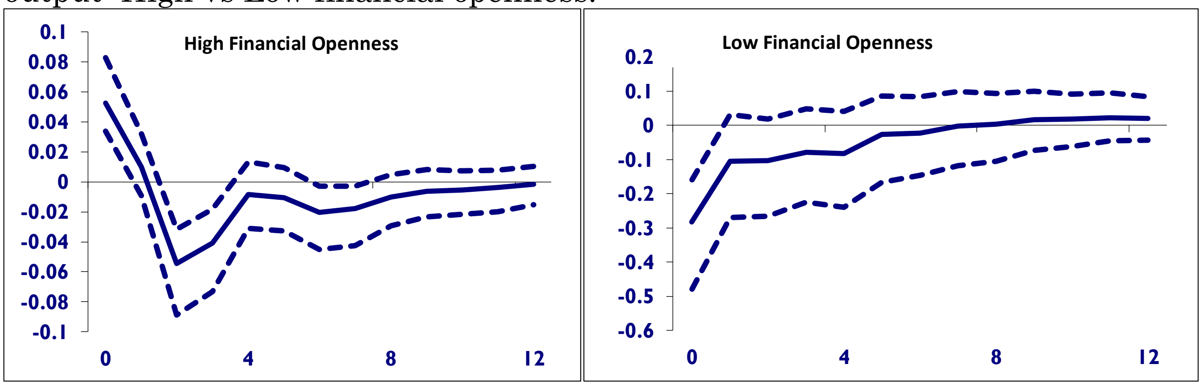
Note: the bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months, and the vertical axes identify percent.

Figure 2.9. The spillover effects of US economic policy uncertainty shock on the output: Advanced economies vs Emerging Economies.



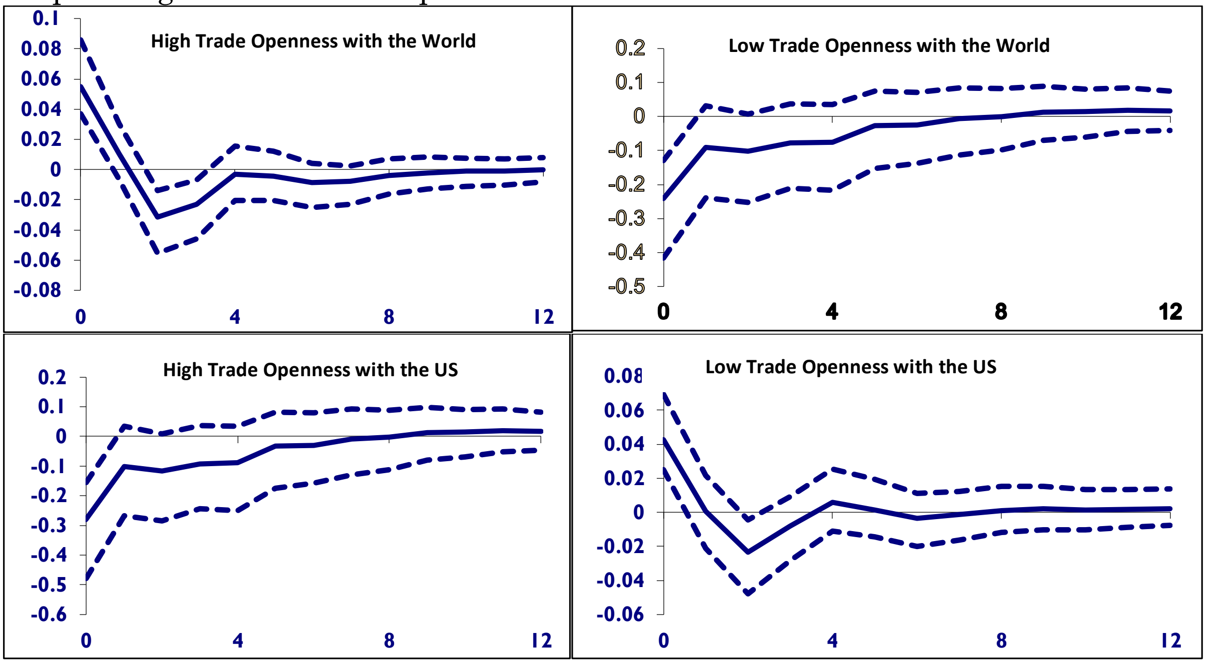
Note: bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months, and the vertical axes identify percent.

Figure 2.10. The spillover effects of US economic policy uncertainty shock on the output: High vs Low financial openness.



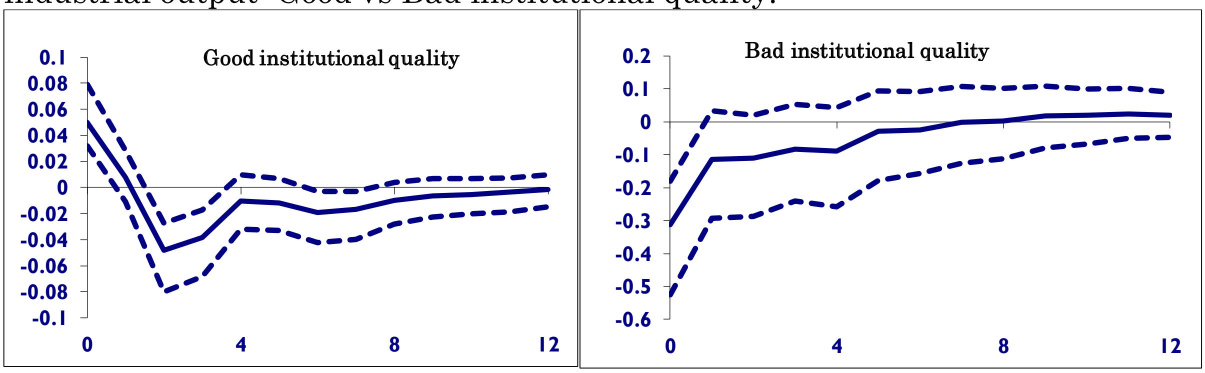
Note: bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months, and the vertical axes identify percent.

Figure 2.11. The spillover effects of US economic policy uncertainty shock on the output: High vs Low trade openness.



Note: bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months, and the vertical axes identify percent.

Figure 2.12. The spillover effects of the US economic policy uncertainty shock on industrial output: Good vs Bad institutional quality.



Note: bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months, and the vertical axes identify percent.

Acknowledgments

I would like to thank Professor Baak Saang Joon, Professor Yoshiaki Ogura, the Editor and the 2 anonymous reviewers of North American Journal of Economics and Finance for their highly valuable comments and suggestions. The remaining errors are the author alone.

Appendixes

Appendix 2.1. The included countries and regions in the GVAR model

Table 2.1. The detail of the countries in empirical analysis

Country/Region	EU	Asian region	Latin America region	Others
UK	Germany	Singapore	Argentina	Saudi Arabia
US	France	Indonesia	Brazil	Turkey
Sweden	Belgium	Thailand	Chile	South Africa
Norway	Finland	Malaysia	Peru	
Switzerland	Italy	Philippine	Mexico	
Japan	Spain	Korea		
Australia	Netherland	China		
Canada	Austria	India		

Appendix 2.2. The exogeneity tests for the foreign and global variables

Table 2.2. The exogeneity tests for the foreign and global variables

Country	F test	Fcrit_0.05	Dp^*_{it}	ind^*_{it}	eq^*_{it}	ep^*_{it}	r^*_{it}	epu^*_{it}	P^O_t
ARGENTINA	F(3,151)	2.66	0.6	0.11	1.81		3.44*	1.3	0.95
AUSTRALIA	F(2,150)	3.06	1.37	0.14	0.44		0.13	1.01	0.67
BRAZIL	F(4,147)	2.43	2.83*	0.72	2.42		1.05	2.09	2
CANADA	F(2,149)	3.06	0.54	0.74	0.77		0.21	3.42	0.27
CHINA	F(2,149)	3.06	1.35	1.65	0.6		0.85	0.72	1.25
CHILE	F(4,147)	2.43	0.42	1.14	2.75		0.52	1.37	1.23
EURO	F(2,149)	3.06	2.51	1.22	4.73*		0.1	1.77	0.74
INDIA	F(2,151)	3.06	0.49	0.74	0.37		3.66*	0.68	0.36
INDONESIA	F(4,148)	2.43	0.38	0.73	2.26		0.38	0.08	1.5
JAPAN	F(3,148)	2.67	2.23	0.06	7.83*		3.92*	0.22	1.21
KOREA	F(4,140)	2.44	5.41*	3.63*	0.71		0.98	1.07	3.69*
MALAYSIA	F(2,150)	3.06	0.6	0.42	0.32		2.23	0.24	0.06
MEXICO	F(3,148)	2.67	0.74	1.15	2.98*		0.49	0.74	0.35
NORWAY	F(3,148)	2.67	0.51	0.73	0.69		1.28	0.26	0.8
PERU	F(2,151)	3.06	0.13	0.4	3.65*		0.13	0.48	0.21
PHILIPPINES	F(1,153)	3.9	0.94	0.05	0.46		0.07	2.81	0.01
SOUTH AFRICA	F(2,150)	3.06	2.61	0.12	0.31		0.28	1.3	0.01
SAUDI ARABIA	F(1,154)	3.9	0.09	0.3	1.47		0.66	0.1	0.3
SINGAPORE	F(2,152)	3.06	2.96	0.28	3.54*		0.35	0.07	3.24*
SWEDEN	F(2,149)	3.06	1.05	2.85	2.22		1.21	0.63	0.98
SWITZERLAND	F(2,150)	3.06	0.1	0.09	0.06		1.25	1.79	0.15
THAILAND	F(2,151)	3.06	3.52*	0.08	3.82*		1.95	1.28	1.76
TURKEY	F(2,151)	3.06	0.35	0.02	0.1		0.7	0.3	0.03
UK	F(3,148)	2.67	0.49	2.54	5.07*		0.18	2.31	0.69
US	F(2,153)	3.06	0.68	0.82		2.9		3.01	

Note: * denotes for significance at 5% level

Appendix 2.3. Generalized Forecast error variance decomposition of the considered variables due to US economic policy uncertainty shock.

Figure 2.13. Generalized Forecast error variance decomposition of the country-specific output due to US economic policy uncertainty shock at first month (percentage).

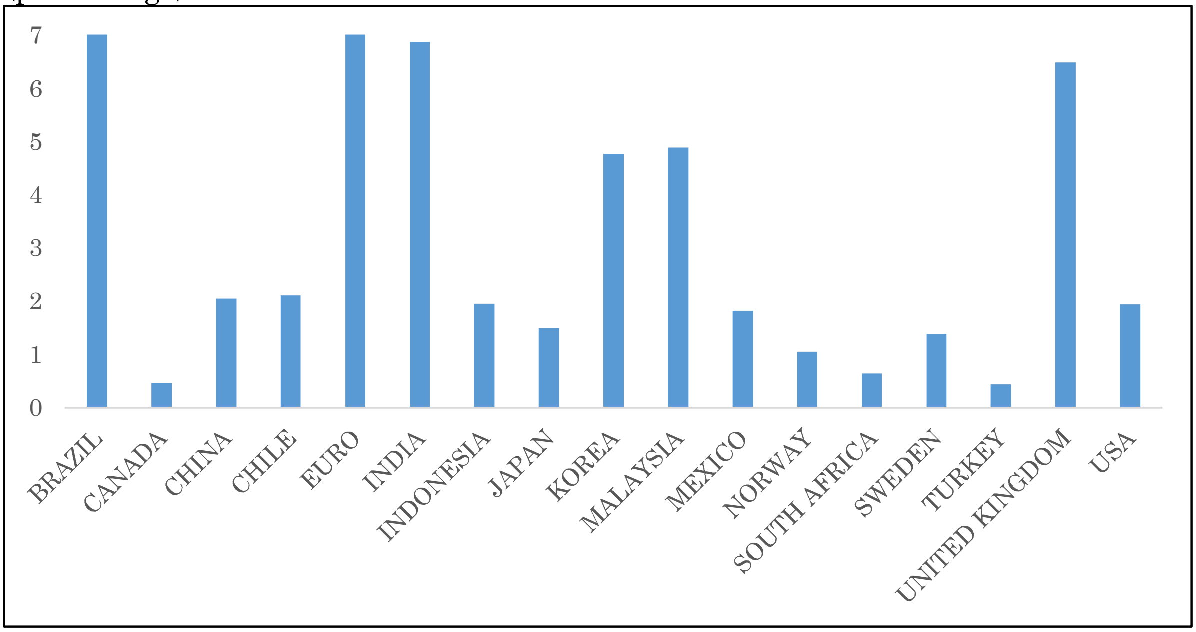


Figure 2.14. Generalized Forecast error variance decomposition of the country-specific capital inflows due to US economic policy uncertainty shock at first month (percentage).

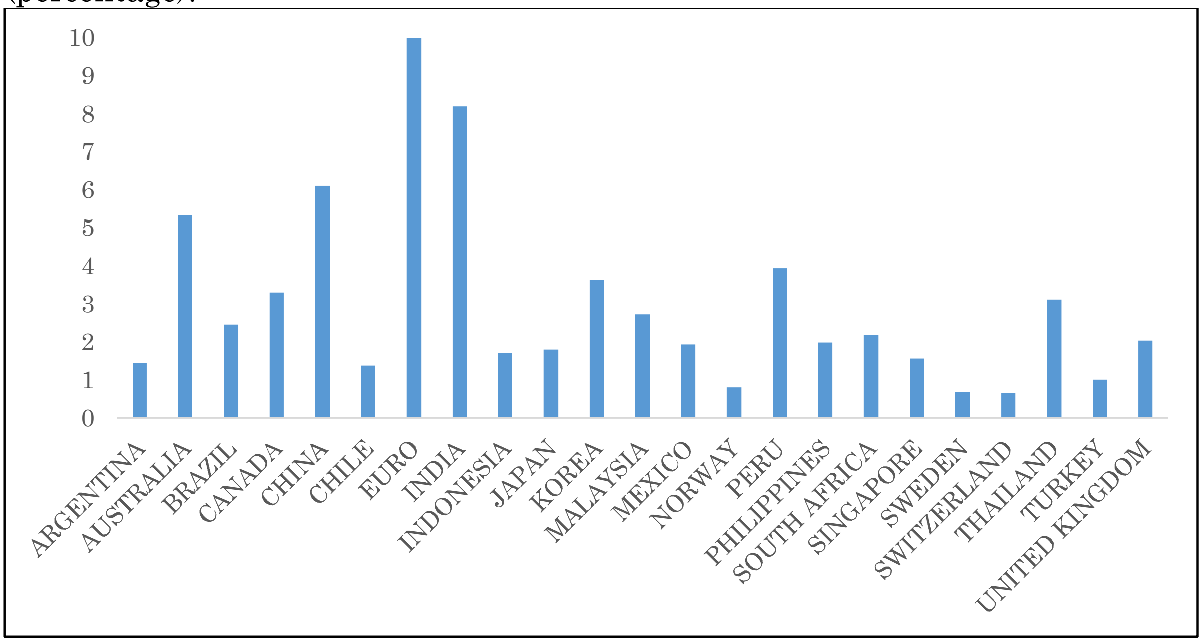


Figure 2.15. Generalized Forecast error variance decomposition of the country-specific short-term interest rate due to US economic policy uncertainty shock at first month (percentage).

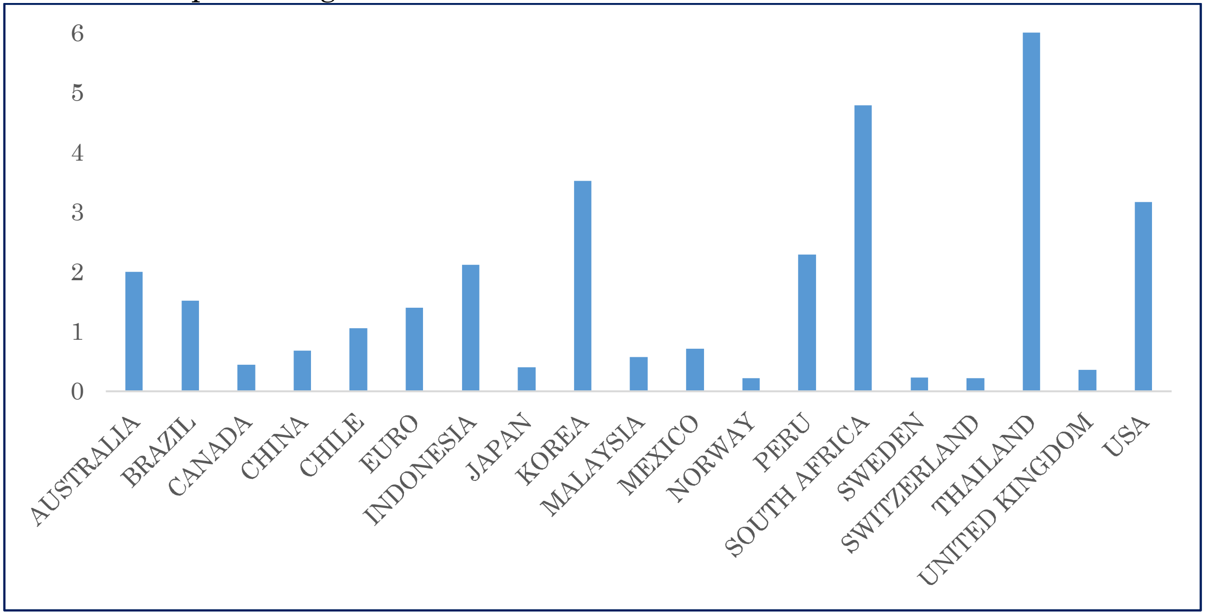


Figure 2.16. Generalized Forecast error variance decomposition of the country-specific inflation due to US economic policy uncertainty shock at first month (percentage).

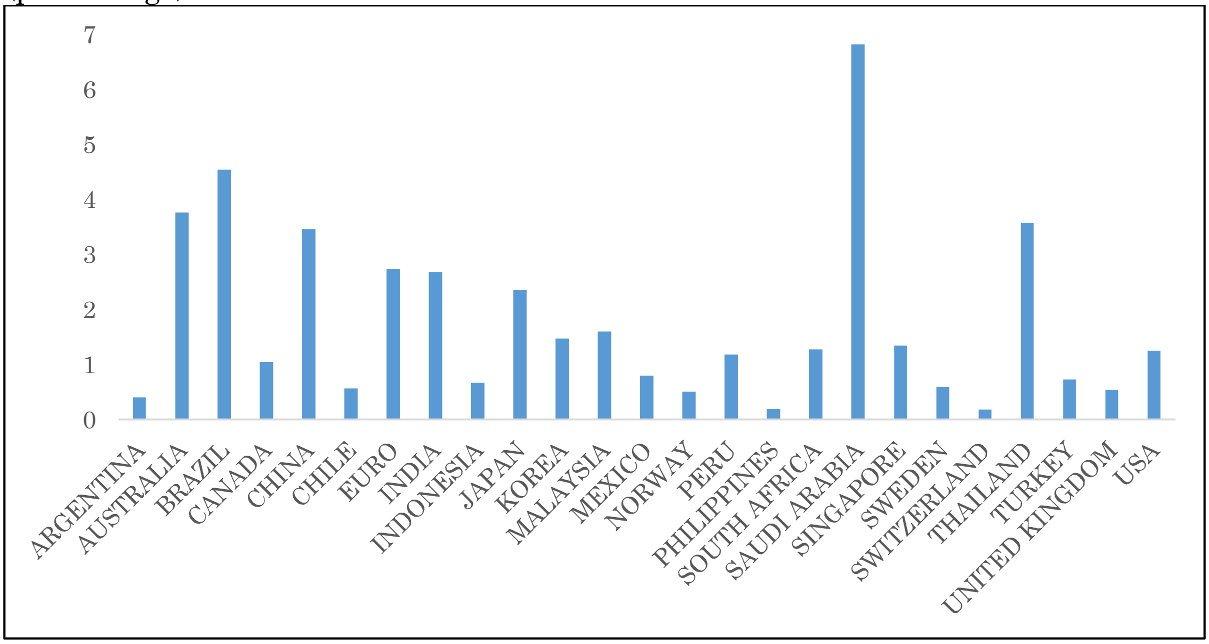
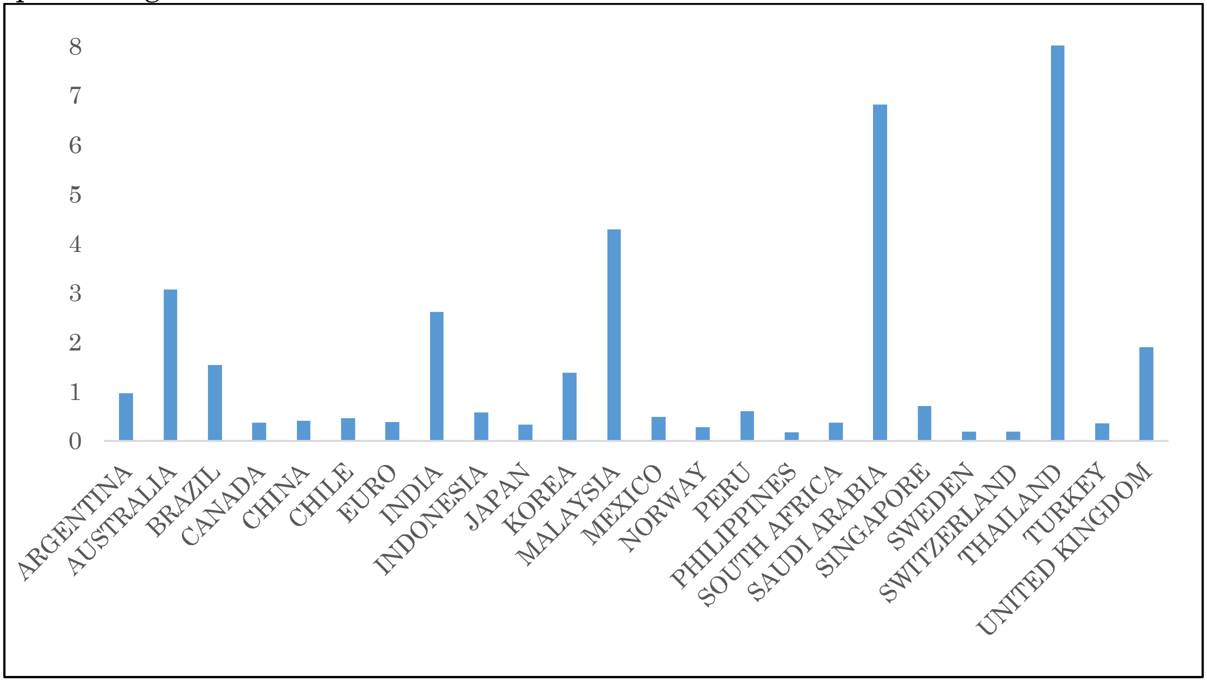
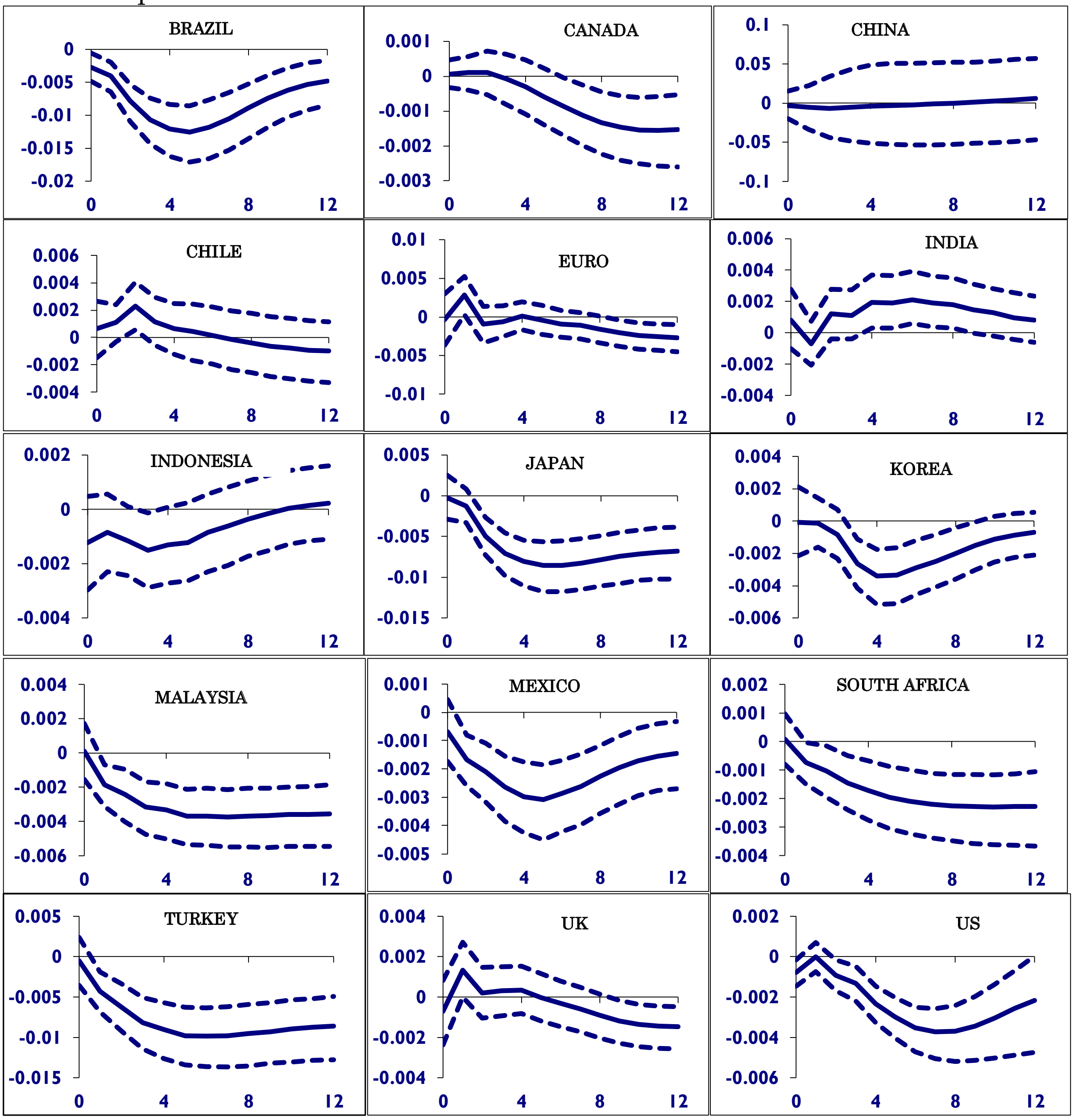


Figure 2.17. Generalized Forecast error variance decomposition of the country-specific exchange rate due to US economic policy uncertainty shock at first month (percentage).



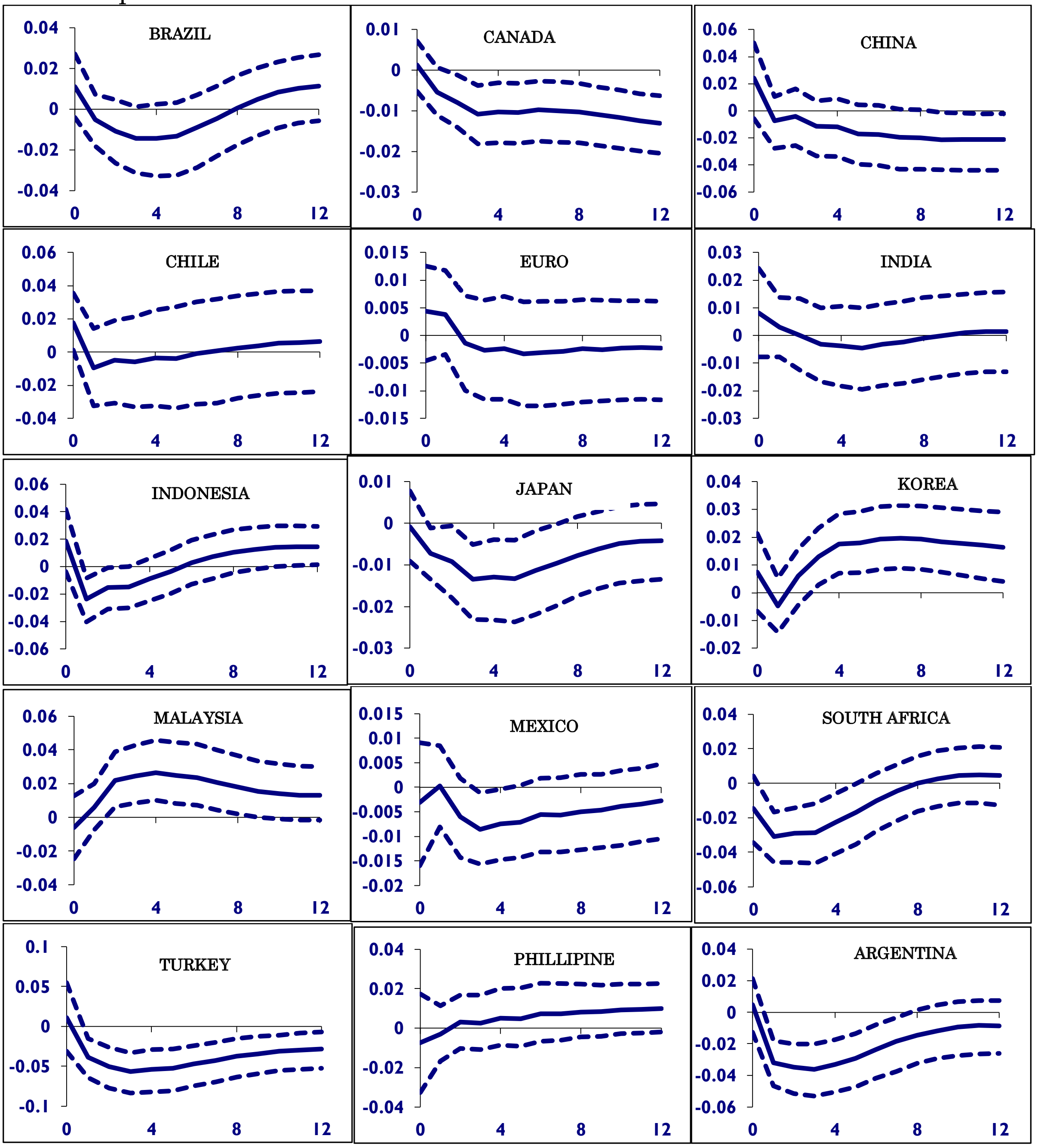
Appendix 2.4. Robustness Analysis

Figure 2.18. The spillover effects of US macroeconomic policy uncertainty shock on the output of other economies.



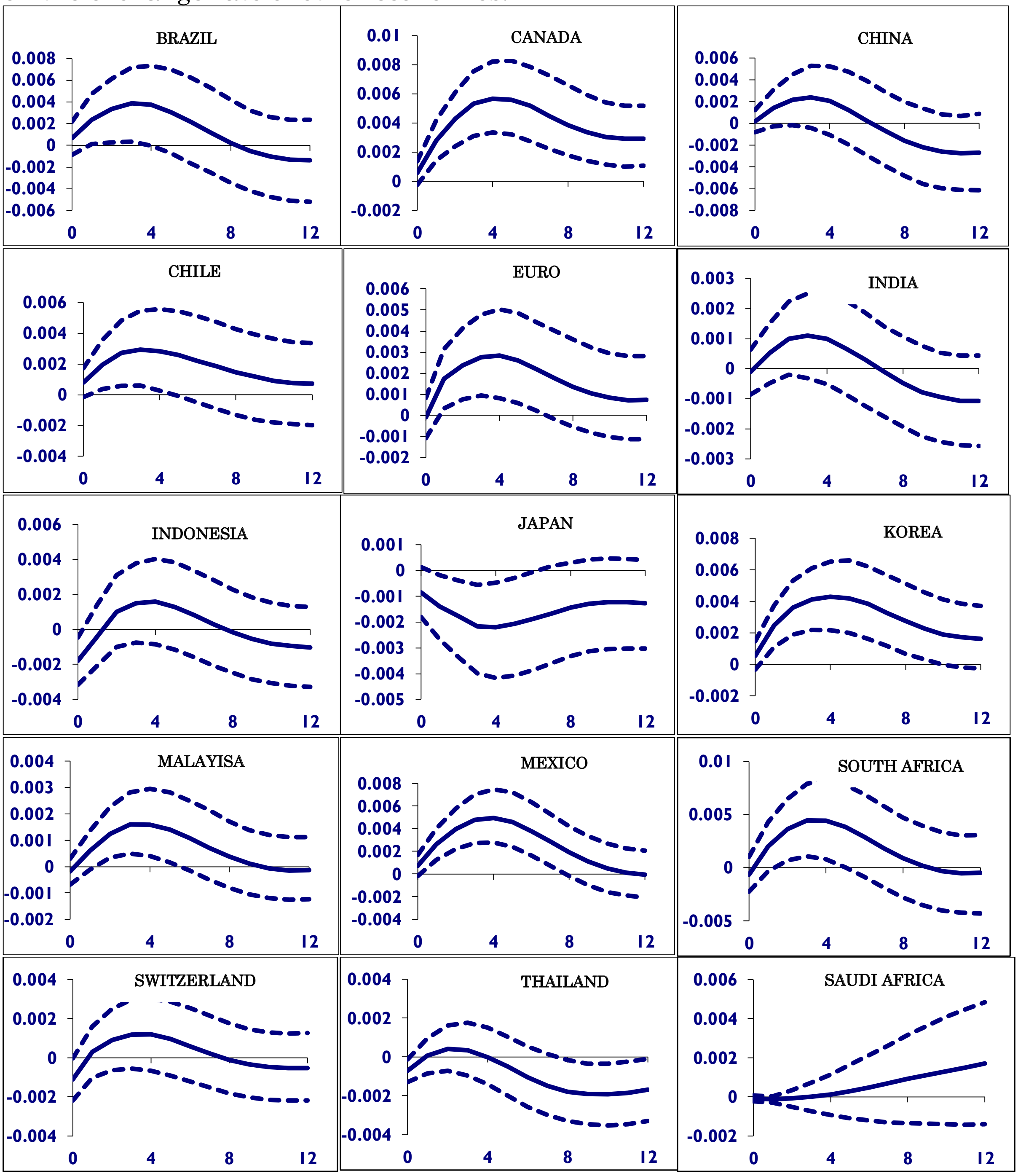
Note: bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months.

Figure 2.19. The spillover effects of US macroeconomic policy uncertainty shock on the capital flows into other economies.



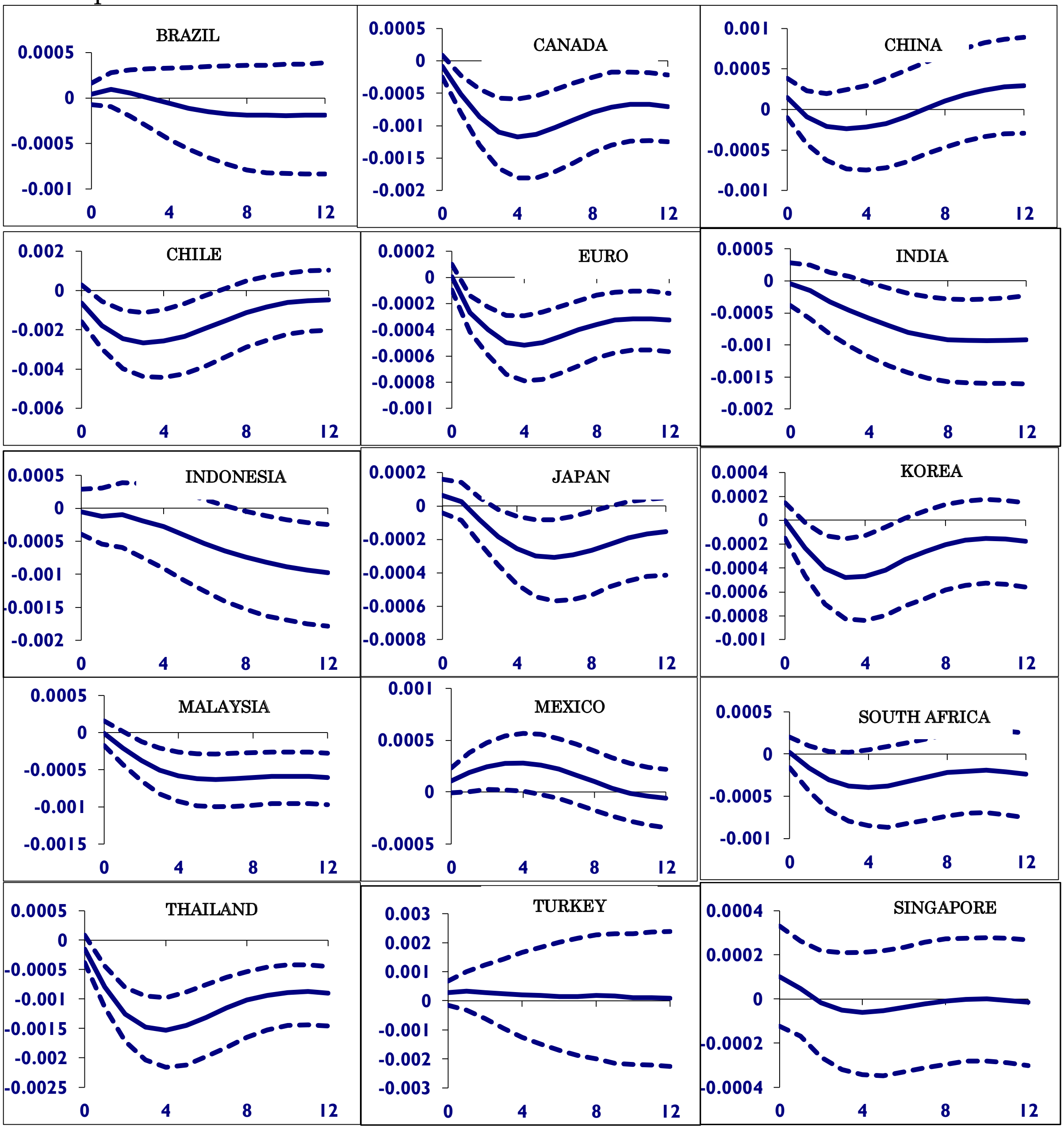
Note: bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months.

Figure 2.20. The spillover effects of US macroeconomic policy uncertainty shock on the exchange rate of other economies.



Note: bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months.

Figure 2.21. The spillover effects of US macroeconomic policy uncertainty shock on the price index of other economies.



Note: bootstrapped median estimates present by the solid lines, and 68% confidence bands illustrate by the dotted lines. The horizontal axes identify months.

Appendix 2.5. The country's characteristics measurement and resources

Table 2.3. The country's characteristics measurement and resources

Indicator	Measurement	Resource
Financial openness	Financial Openness index	Chinn and Ito (2008)
Trade openness with the world	Exports plus imports relative to GDP	WDI database, World Bank
Trade openness with the US	Exports plus imports with the US relative to total trade	
Institutional quality	The average score of the five indicators, including Control Corruption, Government Effectiveness, Political stability, Regulatory quality, Voice and Accountability	Worldwide Governance Indicators, World Bank

Appendix 2.6. The sub-groups of the receiving country's characteristics

Table 2.4. The sub-groups of the receiving country's characteristics

Country	Level of development	Financial openness	Trade openness with the World	Trade openness with the US	Institutional quality
ARGENTINA	L	L	L	L	L
AUSTRALIA	H	H	L	L	H
BRAZIL	L	L	L	H	L
CANADA	H	H	H	H	H
CHINA	L	L	L	H	L
CHILE	L	H	H	H	H
INDIA	L	L	L	L	L
INDONESIA	L	L	L	L	L
JAPAN	H	H	L	H	H
KOREA	L	L	H	H	H
MALAYSIA	L	L	H	H	H
MEXICO	L	L	L	H	L
NORWAY	H	H	L	L	H
PERU	L	H	L	H	L
PHILIPPINES	L	L	H	H	L
SOUTH AFRICA	L	L	H	L	L
SAUDI ARABIA	L	H	H	H	L
SINGAPORE	L	H	H	L	H
SWEDEN	H	H	H	L	H
SWITZERLAND	H	H	H	L	H
THAILAND	L	L	H	L	L
TURKEY	L	L	L	L	L
UK	H	H	L	L	H

Notes: Countries which mean value of the respective measure over the sample period lies above the median over countries are grouped into the respective "high" (= H) group, countries which mean value lies below the median are grouped as "low" (= L).

Chapter 3. Monetary policy uncertainty and economic fluctuations

Abstract

This paper examines the effects of monetary policy uncertainty on economic activities. We first propose a simple econometric method for measuring monetary policy uncertainty. Our main idea is that monetary policy is more uncertain when monetary policy is less predictable, represented as the percent deviations of actual interest rate from its optimal policy rate. We also adjust for unconventional monetary policies implemented after the 2007-2008 global financial crisis by using two extra auxiliary sources, including uncertainty about central bank's communications and quantitative easing policy. We combine three resources to create an overall measurement for monetary policy uncertainty based on a GARCH(1,1) model with principle component analysis. We illustrate our methodology for the US economy, and find that our index is well fitted with the experience of monetary uncertainty shocks in the US economy. Finally, using a VAR model, we figure out that monetary policy uncertainty shock has a negative effect on real economic activities. This effect is more sizeable and persistent during the great depression. Our findings partly help explain the slow recovery of the global economy after the global financial crisis.

Keywords: Monetary policy uncertainty; the US economy; Monetary policy; VAR model; Uncertainty, Orthogonal GARCH model

JEL classifications: E40, E50, E52

3.1. Introduction

Nowadays, central bank across globe has recognized the crucial importance of increasing transparency and public communication in conducting monetary policy. The public communications involves the forward guidance from the central bank about how is the likely future course of monetary policy. Following on the forward guidance from the central bank, economic agents has been able to predict about the current and future monetary policies, which are an important function of economic conditions (Blinder et al. 2008). As a result, transparency and public communications not only increase effectiveness of monetary policy but also encourages investment and spending because of lower uncertainty in monetary policy.

After the 2007-2008 global financial crisis and the great depression, advanced economies have conducted various unconventional macroeconomic policies to accelerate the recovery of the economy. Consequently, economic policy uncertainty has significantly increased and driven the business cycle fluctuations of the global economy (Nicholas Bloom 2014; Castelnuovo, Lim, and Pellegrino 2017). A large number of theoretical and empirical studies have focused on measuring economic uncertainty and its effects on economic activities (see e.g., Nicholas Bloom 2009; Jurado, Ludvigson, and Ng 2015; Baker, Bloom, and Davis 2016; Bachmann, Elstner, and Sims 2013). In this paper, we focus on measuring monetary policy uncertainty and examine how it affects real economic activities.

Our article relates, at least, two strands of the current literature. The first is the literature of measuring monetary policy uncertainty (Mumtaz and Zanetti 2013; Baker, Bloom, and Davis 2016; Sinha 2016b; Husted, Rogers, and Sun 2017; Creal and Wu 2017; Istrefi and Mouabbi 2018). However, our approach is different by three features. First, unlike to the previous studies, using the newspaper coverage of monetary policy uncertainty or events study (see e.g., Baker et al., 2016; Husted et al., 2017; Kurov & Stan, 2018), we directly construct monetary policy uncertainty from unpredictable interest rate. This feature is important as interest rate policy, as an important function of economic conditions, has more power in driving the behavior of all agents (e.g., households, firms, banks etc.) in the economy. Second, we construct monetary policy uncertainty based on forward-looking interest rate setting. This approach is more realistic because of allowing the effects of the future economic conditions on current monetary policy decisions (Clarida, Galí, and Gertler 2000; Bernanke 2010). This feature, however, does not capture by the previous studies, for example, using a VAR model with stochastic volatility (see e.g., Mumtaz and Zanetti 2013). Third, after the 2007-2008 global financial crisis, the central banks of advanced economies have implemented various unconventional monetary policies (e.g., zero low bound interest rate and quantitative easing policy). Therefore, volatility of unpredictable interest rate does not enough capture the comprehensive dimensions of monetary policy uncertainty. We address this challenge by using extra two auxiliary resources. During the great depression, the central banks of leading economies have inhibited monetary uncertainty by increasing public communication via forward guidance on interest rate setting and economic outlooks (Kurov and Stan 2018). However, Cukierman (2009) remarked that the central bank holds private information about problems of the economy, and thus release of such information can be potential harmful and confused to the market. Blinder et al. (2008) further noted that more dispersion in central bank's communication could increase uncertainty about monetary policy. We, therefore, use the newspapers coverage index of monetary policy uncertainty – proposed by Husted, Rogers, and Sun (2017) – to capture for uncertainty about central bank's communication. Furthermore, after the 2007-2008 global financial crisis, the central banks of advanced economies have pursued a long period of quantitative easing policy. This has created widely fluctuations in financial markets and economic activities (see, e.g., Joyce et al. 2012). Thus, we use another extra resource, measured by money supply volatility, to capture for uncertainty about quantitative easing and zero low bound policy. From three resources, we employ a univariate GARCH model with principle component analysis to construct the overall measurement for monetary policy uncertainty. As a result, our approach captures better the comprehensive dimensions of monetary policy uncertainty.

Second, our paper also relates to the literature of quantifying the effects of monetary policy uncertainty shock on real economic activities (Fernández-Villaverde et al. 2011a; Herro and Murray 2013; Kurov and Stan 2018; Mumtaz and Zanetti 2013; Sinha 2016b). We confirm the previous studies by showing that monetary policy uncertainty shock has a negative effect on economic activities. However, by capturing the comprehensive dimensions of monetary policy uncertainty, our estimated effects of monetary policy uncertainty shock are more sizeable than the previous studies. We further find that the effects of monetary policy uncertainty shock are more sizable and persistent after the 2007-2008 global financial crisis. For example, during the great depression, investment and output decline approximately three time as much as that of the pre-crisis periods.

Our findings partly help explain the slow recovery of the world economy after the 2007-2008 financial crisis.

The rest of this chapter is organized as follows. Section 3.2 presents the methodology for measuring monetary policy uncertainty. Section 3.3 examines the effects of monetary policy uncertainty shock on real economic activities. Section 3.4 is the robustness analysis where we confirm our empirical results by using different model specifications. The conclusions and suggestions are outlined in Section 3.5.

3.2. Measuring monetary policy uncertainty

3.2.1. Methodology

Following Clarida, Galí, and Gertler (2000), in each period, the central bank choose optimal nominal interest rate as follows:

$$i_t^* = \bar{i} - \delta\pi^* + \delta E_t(\pi_{t+k} \mid \Omega_t) + \beta \mathrm{E}_t(y_{t+k} \mid \Omega_t) \quad (3.1)$$

Where i_t^* is the optimal nominal interest rate, $\bar{i}$ is the desired nominal rate when both inflation and output gap at their targets. π is the inflation rate, and π^* is the target inflation rate, and y is the output gap, defined as the percent deviation of real output from its target. Therefore, $E(\pi_{t+k})$ and $\mathrm{E}(y_{t+k})$ are the expectation of future inflation and output gap, and Ω_t is the information available to the central bank at the time that the policy rule is set.

We assume that actual nominal interest rate adjusts toward the desired rate by:

$$i_t = \rho i_{t-1} + (1-\rho)\mathrm{i}_t^* + \zeta_t \qquad (3.2)$$

Where i_t^* is determined by (3.1). The term ζ_t represents for exogenous random shocks. Substituting (3.1) into (3.2) and defining $\alpha = \bar{i} - \delta\pi^*$, we obtain:

$$i_t = \rho i_{t-1} + (1-\rho)[\alpha + \delta E_t(\pi_{t+k} \mid \Omega_t) + \beta \mathrm{E}(\mathrm{y}_{t+k} \mid \Omega_t)] + \zeta_t \quad (3.3)$$

If policy-makers can observe perfectly all information (Ω_t) at the time that the policy rate is set (e.g., the current and future state of the economy), they can then predict accurately the future inflation and output gap. This is, $\pi_{t+k} = E(\pi_{t+k} \mid \Omega_t)$ and $y_{t+k} = \mathrm{E}(\mathrm{y}_{t+k} \mid \Omega_t)$. However, in reality, the information available to policy-makers is imperfect (e.g., unpredictability about the current and future state of the economy). For this reason, we assume that:

$$\pi_{t+k} = E(\pi_{t+k} \mid \Omega_t) + \varepsilon^{\pi}_{t+k} \quad (3.4)$$

$$y_{t+k} = E(\mathrm{y}_{t+k} \mid \Omega_t) + \varepsilon^{y}_{t+k} \quad (3.5)$$

Where ε^{π}_{t+k} and ε^{y}_{t+k} are the estimated error of future inflation and output gap. In other words, ε^{π}_{t+k} and ε^{y}_{t+k} represent for the imperfect observations of the current and future state of the economy that affect the current monetary policy decisions. Plugging (3.4) and (3.5) into (3.3), we obtain:

$$i_t = \rho i_{t-1} + \alpha(1-\rho) + \delta(1-\rho)\pi_{t+k} + \beta(1-\rho)\,\mathrm{y}_{t+k} + u_t \quad (3.6)$$

Where $\mathrm{u}_t = \zeta_t - \delta(1-\rho)\varepsilon^{\pi}_{t+k} - \beta(1-\rho)\varepsilon^{y}_{t+k}$ is the composited error term, measured by the percent derivation of actual nominal interest rate from its optimal target. The composite term u_t in (3.6) can be viewed as unpredictable interest rate setting, which is a valid proxy for monetary policy uncertainty (Romer and Romer 2004; Martin and Milas 2009; Jurado, Ludvigson, and Ng 2015; Istrefi and Mouabbi 2018). In other words, the imperfect information about the current and future conditions of the economy triggers current monetary policy setting being uncertain.

After the 2007-2008 global financial crisis, the central banks of advanced economies have implemented various unconventional monetary policies, such as zero low bound interest rate policy and quantitative easing. As a result, unpredictable interest rate in (3.6) does not enough capture the comprehensive dimensions of monetary policy uncertainty.

To deal with the great depression, the central bank implemented the zero low bound interest rate policy and pursued a long period of quantitative easing policy. These policies lead to wide fluctuations in financial markets and economic activities (see, e.g., Joyce et al. 2012). We, therefore, use volatility of money supply growth as an extra auxiliary resource to capture for uncertainty about unconventional monetary policy after the crisis, including uncertainty about the zero low bound interest rate policy and quantitative easing.

In recent years, the central banks of advanced economies have implemented large-scale asset purchase programs to stimulate the economy, increase inflation towards its targeted level (Gagnon and Sack 2018). These programs expanded the central bank's balance sheet to unprecedented level. The current literature has mainly examined the effects of quantitative easing on financial market, in which quantitative easing measures are often proxy as announced amount of asset purchases, central bank' balance sheet, and money base (Koeda 2019). However, few studies have investigated the macroeconomic effects of quantitative easing, especially output and inflation as our interest here (Kapetanios et al. 2012). As suggested by the quantity theory of money, quantitative easing and zero low bound policy will drive up money supply, and thus leading an increase in price index. However, in reality, it seems that quantitative easing and zero low bound policy do not affect inflation (Czeczeli 2016; Chen, Cúrdia, and Ferrero 2012). For example, Chen, Cúrdia, and Ferrero (2012) examined the effects of the second round of the asset purchases program of the Fed, and they found that this program has limited effect on inflation. Feldstein (2012) explained that excess reserves caused by asset purchase programs do not trigger the rapid credit growth, and thus money supply because the Fed began in October 2008 to pay interest on those reserves of commercial banks. As a result, commercial banks prefer to place their excess reserves at the Fed rather than lending them to the private sectors. In other words, not all surplus reserves caused by quantitative easing are translated into the economy and money supply. This is reason why from 2008 to 2011, the Fed increased its balance sheet more than 40 times (from $400 billion to $1.6 trillion); however, the growth of money supply increased only by 25% (Feldstein, 2012). As a result, the first quantitative easing (QE1) was not efficient to pull out the US economy from recession, and raise inflation to its target, leading the Fed to conduct the second quantitative easing (QE2) in 2010 and the third quantitative easing (QE3) in 2012 (Gagnon and Sack 2018). We, therefore, prefer to use the money supply at here to account for the real effects of quantitative easing and zero low bound policy. This is that we only examine the real proportion of quantitative easing that contributes to the growth of money supply, which in turn affects price and output as suggested by the quantity theory of money. Furthermore, after the crisis, the central banks of advanced economy have implemented the zero low bound policy and committed to maintain interest rate at near zero for a long period. The monetary policy instrument based on interest rate setting in (3.6) has no room for adjustments, and also no longer effective to pull out the economy from recession. The central banks, therefore, altered their instrument to unconventional monetary policies (e.g., quantitative easing), aiming to increase money supply, and thus stimulus the economy. Therefore, using money supply here is better to capture both the behavior of the central bank and the real effects of quantitative easing after the global financial crisis.

Following (3.6), the central bank will set money supply growth as follows[17]:

$$\Delta m_t = \rho_m \Delta m_{t-1} + \alpha_m (1-\rho_m) + \delta_m (1-\rho_m)\pi_{t+k} + \beta_m (1-\rho_m)\,\mathrm{y}_{t+k} + \omega_t \qquad (3.7)$$

where $\omega_t = \zeta_{t,m} - \delta_m (1-\rho_m)\varepsilon^{\pi}_{t+k} - \beta_m (1-\rho_m)\varepsilon^{y}_{t+k}$ is the percent deviation of money supply growth from its target. Similar to the composite term u_t in (3.6), the composite term ω_t can be viewed as a valid proxy for uncertainty about zero low bound policy and quantitative easing.

Finally, another monetary policy instrument that the Fed and other major central banks have conducted after the global financial crisis is the communication and forward guidance (Svensson 2011). During the great depression, the central banks have inhibited monetary uncertainty by increasing public communication via forward guidance about interest setting and economic outlooks (Kurov and Stan 2018). However, Cukierman (2009) noted that the central bank holds private information about problems of the economy; thereby release of such information can be potential harmful and volatile to the market. Ehrmann and Fratzscher (2007) exposed that more dispersion in central bank's communication can increase uncertainty about monetary policy setting. We, therefore, use the newspaper

[17] This is similar to the spirit of Orphanides (2003) and Pierdzioch (2004)

coverage of monetary policy uncertainty index (named as the HRS index) – proposed by Husted, Rogers, and Sun (2017)– as another auxiliary resource to capture uncertainty about central bank's communication and forward guidance.[18] We now have three sources to construct monetary policy uncertainty index. The main source is the unpredictable interest rate (u_t) in (3.6) while the two auxiliary resources are the uncertainty about quantitative easing policy (ω_t) in (3.7) and uncertainty about central bank's communication (the HRS index). Our challenge is now to combine them to produce the overall measurement for monetary policy uncertainty. To solve this, we use a univariate GARCH model with principle component analysis. The principle component GARCH model is proposed by Alexander (2001) and employed widely in measuring volatility of financial market (see, e.g., Byström, 2004; Luo, Seco, & Wu, 2015).

Suppose that we have K time series with T observations, represented as a TxK matrix, Y_t. Since, the principle component analysis is very sensitive to the scale of the data, Y_t is often normalized to have mean zero and unit variance.

Then TxK matrix, P_t, principle components, are defined as:

$$P_t = Y_t W_t \quad (3.8)$$

[18] Baker, Bloom, & Davis (2016) proposed a similar measurement (named as the BBD index). However, we prefer to Husted, Rogers, & Sun (2017). See detail reasons discussed in the section 2.4.1 in the Chapter 2.

Where W_t is the orthogonal KxK matrix of eigenvectors of $Y'Y$, which are ordered according to the size of the corresponding eigenvalues. Because W is an orthogonal matrix, we can rewrite (3.8) as follows:

$$Y_t = P_t W_t' \quad (3.9)$$

The variance of Y in (3.9) then is defined as:

$$V = \operatorname{var}(Y_t) = W_t \operatorname{var}(P_t) W_t' = W_t D W_t' \qquad (3.10)$$

Where $\mathrm{D} = \operatorname{var}(P_t)$ is a diagonal matrix of the principle component variances. We assumed that each principle component with conditional variance is followed a univariate GARCH(1,1) as:

$$\begin{aligned} P_t &= \sigma_t \varepsilon_t \\ \sigma_t^2 &= \theta_0 + \theta_1 \varepsilon_t^2 + \theta_2 \sigma_{t-1}^2 + v_t \end{aligned} \qquad (3.11)$$

Where v_t is assumed as N(0,1).

We, then, define our monetary policy uncertainty as:

$$MPU = \sqrt{\operatorname{var}(Y_t)} = \sqrt{W_t D W_t'} \quad (3.12)$$

3.2.2. Constructing monetary policy uncertainty for the U.S

In this section, we construct monetary policy uncertainty index for the US economy by using (3.6), (3.7), (3.10), (3.11), and (3.12). We use quarterly data from 1985Q1 to 2017Q4. We follow Clarida, Galí, and Gertler (2000) to use one period ahead for inflation and output gap, and use fed fund rate (i_t) as the measure for short-term nominal interest rate, and GDP deflator (π_t) as the measure for inflation. For output gap, we obtain from U.S. Congressional Budget Office.

We first estimate (3.6) and (3.7) using iterated GMM method and lags of the variables as instruments. The detail results of (3.6) and (3.7) are provided in Appendix 3.1. The estimated errors $\hat{u}_t$ in (3.6) and $\hat{\omega}_t$ in (3.7), and the HRS index are used to extract composited components using principle component analysis. The principle component analysis is a multivariate statistical method to reduce the dimension of the observed variables to a smaller number of principal components, which are uncorrelated and account for the most of the variance in the initial variables. The principle component analysis, therefore, synthesizes the data with less loss of information (Jolliffe 2002). In principle component analysis, the maximum number of principle components created is equal to the number of the initial variables. However, only the first few components are retained because they accounts for the maximal amount of the total variance of the initial variables (Jolliffe 2002; Alexander 2001). In our case, we use only first two-extracted principle components, and they account for approximately 80% of the total variance of the initial variables. The principle components are constructed as a linear combination of the optimally weighted observed variables[19]. The detail results of principle component analysis are provided in Appendix 3.2. We note that the first principle component is negative correlated with interest rate uncertainty ($\hat{u}_t$) but positive correlated with uncertainty about quantitative easing policy ($\hat{\omega}_t$) and central bank's forward guidance (the HRS index). This is well fitted with the recently downward trend in interest rate volatility and upward trend in volatility of money supply growth and central bank's communication. We, therefore,

[19] See Jolliffe (2002) for further explanation.

attribute the first principle component as the trend component of monetary policy uncertainty. The second principle component is positive correlated with uncertainty about interest rate and central bank's public communication but negative correlated with uncertainty about quantitative easing policy. Referring to our data, changes in uncertainty about interest rate and central bank's public communication have a positive slope on average but negative for uncertainty about quantitative easing policy. We, therefore, attribute the second principle component as the changes in the slope of monetary policy uncertainty. The extracted principle components are now used to estimate (3.11), and then generate monetary policy uncertainty index for the US using (3.10) and (3.12). The detail results of (3.11) are provided in Appendix 3.3.

Note that (3.10) is the variance matrix of the three separate resources. However, as discussed above, our main resource in measuring monetary policy uncertainty is the unpredictable interest rate (u_t in (3.6)) while uncertainty about quantitative easing and zero low bound policy (ω_t in (3.7)) and central bank's communications (the HRS index) are the two auxilary resources to account for unconventional monetary policies after the global financial crisis. Therefore, our main monetary policy uncertainty index is mainly defined as the variance of the unpredictable interest rate in (3.10). The detail results of (3.11) are provided in Appendix 3.3.

We depict the monetary policy uncertainty index for the US in Figure 3.1. For comparison, we illustrate two monetary policy uncertainty indexes. The first is the main result using all the three resources, denoted as MPU. The second use only the interest rate uncertainty ($\hat{u}_t$ in (3.6)) estimated via an univariate GARCH(1,1) model, denoted as INU. It is worth noting that our MPU index is well fitted with the experience of monetary shocks in the US economy, spiking nearly tight to the early 1990 recession, the 2007-2008 financial crisis, the periods of quantitative easing and zero low bound interest rate policy, and recent monetary policy tightening. For the INU index, it is striking to note that it has the same path as the MPU index before the 2007-2008 global financial crisis. However, after the global financial crisis, the INU index is less volatile because of the zero low bound interest rate policy. This implies that using only interest rate volatility does not enough capture the comprehensive dimensions of monetary policy uncertainty. By contrast, during the great depression, the MPU index shows higher volatility and capture better the monetary uncertainty caused by zero low bound interest rate and quantitative easing policy, forward guidance, and recent monetary policy tightening.

Insert Figure 3.1 here

We proceed to evaluate our index in comparison with some alternative measurements, tabulated in Table 3.1. As shown in the previous section, our approach is that uncertainty about the current and future state of the economy triggers the current monetary policy setting being uncertain. As a result, our measurement is positive and highly correlated with some macroeconomic policy uncertainty indexes, for example the macroeconomic policy uncertainty index of Jurado, Ludvigson, and Ng (2015), the economic policy uncertainty index of Baker, Bloom, and Davis (2016), and the VXO index (measure as the volatility index of 30-day option on the S&P 100 stock index). We continue to compare with some other existing monetary uncertainty measurements. We find that our measurement is also positive and moderate correlated with the monetary policy uncertainty index of Baker, Bloom, and Davis (2016) and the interest rate uncertainty based on disagreements among forecasters of Istrefi and Mouabbi (2018).

Insert Table 3.1 here

3.3. Monetary policy uncertainty and economic fluctuations

In this section, we consider the effects of monetary policy uncertainty on economic activities. We estimate a VAR model for the US economy as below:

$$x_t = \phi_0 + \sum_{i=1}^{T} \phi_i x_{t-i} + \eta_t \qquad (3.13)$$

Our main variables (x_t) are real GDP (Y), real investment (INV), real consumption (CONS), unemployment (UN), consumer price index (CPI), and our monetary policy uncertainty index (MPU), and short interest rate (INT). All variables are formed in log, except for UN, MPU, and INT. We also include a time trend in (3.13) to control for unobserved effects. We estimate (3.13) using five lags length as suggested the AIC criteria. We examine the effects of monetary policy uncertainty shock using a short-run cholesky decomposition ordered as follows:

$$\begin{vmatrix} MPU \\ INV \\ CONS \\ UN \\ Y \\ CPI \\ INT \end{vmatrix}$$

We consider the responses of real economic activities to a one standard deviation shock to monetary policy uncertainty in Figure 3.2. In general, we find that monetary policy uncertainty shock significantly drives the economic fluctuations in the US economy. In particular, monetary policy uncertainty shock is estimated to be significantly negative for investment, reaching the lowest fall at around 2% after 5 quarters. This effect is the same for consumption but smaller in magnitude, declining at around 0.4% after 4 quarters. We note that these findings here are highly consistent with the "wait-and-see" effect in the literature (Nicholas Bloom 2009; Jurado, Ludvigson, and Ng 2015; Bernanke 1983). We further show that investment channel seem to be more vulnerable than consumption channel following monetary policy uncertainty shock. This result is more rational in sense that firms, on average, are more concerned about uncertainty than households are (Nicholas Bloom 2017).

Insert Figure 3.2 here

By declining investment and consumption, we also find that monetary policy uncertainty shock leads to an increase in unemployment and a drop in output. The unemployment rate is estimated to raise to the highest level at around 0.2% after 4 quarters, while real output reaches the lowest fall at around 0.5% after 4 quarters. In addition, by depressing the domestic demands regarding investment and consumption, monetary policy uncertainty shock triggers a small deflation. The price index is estimated to decline around 0.25% after 4 quarters. Finally, short-term interest rate is also estimated to fall after monetary policy uncertainty shock. This effect, however, is insignificant.

Before closing this section, we examine how important is monetary policy uncertainty shock? To answer this question, we examine the forecast error variance decompositions (FEVDs) of our considered variables in Table 3.2.

We first underline that economic activities are estimated to respond strongly to monetary policy uncertainty shock. For example, monetary policy uncertainty can explain large fluctuations of real economic activities, approximately 22.3% for investment, 21.1% for consumption, 24.4% for unemployment, and 24% for output after 6 quarters. For price index and short-term interest rate, they are approximate 20.83% and 0.96%, respectively.

Insert Table 3.2 here

The literature has argued that uncertainty is the main cause for the slow recovery of the global economy after the 2007-2008 global financial crisis (Stock and Watson 2012; IMF 2013). In this section, we will grasp this issue by comparing the effects of monetary policy uncertainty shock before and after the 2007-2008 financial crisis. We split our sample into two sub-samples, including before and after the global financial crisis. We estimate the VAR model for the two sub-samples as presented in (3.13). Due to the small sample period, we use only one lag length as suggested by SIC criteria. We first examine the effects of monetary policy uncertainty before the global financial crisis in Figure 3.3. We note that the responses of economic activities are also estimated to be negative after monetary policy uncertainty shock. However, this effect is smaller in magnitude. For example, investment depresses to the lowest level only around 1% after 4 quarters. Consumption is estimated to be negative but insignificant. The output also drops to the lowest level at approximately 0.2% after 4 quarters, which is coincidental with the period of the largest fall in investment.

Insert Figure 3.3 here

We now turn to empirical results after the 2007-2008 global financial crisis, depicted in Figure 3.4. We figure out that monetary policy uncertainty shock now indicates larger effects on economic activities. For instance, investment declines three times as much as that of the pre-crisis periods, reaching the lowest fall to rough 3%. Similarly, the output drops more than before the global crisis, reaching the lowest level at around 0.5% after 4 quarters. We further note that the responses of economic activities are now estimated to be more persistent than the pre-crisis periods. Our findings, therefore, partly help explain the slow recovery of the global economy after the 2007-2008 global financial crisis.

Insert Figure 3.4 here

3.4. Robustness Analysis

In this section, we examine the robustness of our empirical results by using different model specifications as follows:

Using the different lag length of the variables

We estimate again our model (3.13) using 2 lags length as suggested by SIC criteria. Our empirical results are provided in Appendix 3.5. The robustness analysis shows that our empirical results are highly consistent. In other words, monetary policy uncertainty is statistically significant and indicates negative effects on real economic activities.

Using the different orders of the variables

We also re-estimate our model using the different orders of the variables, in which the short-term interest rate and price index are placed first after monetary policy uncertainty.

$$\begin{vmatrix} MPU \\ INT \\ CPI \\ CONS \\ INV \\ UN \\ Y \end{vmatrix}$$

The results of the robustness analysis, provided in Appendix 3.5, also confirm that our emprirical reuslts are highly consistent.

Using different monetary policy uncertainty measurement

We now compare our results with using other monetary policy uncertainty index – named as the BBD index – proposed by Baker, Bloom, and Davis (2016). The empirical results of using the BBD index are outlined in Appendix 3.6. We first note that our empirical results are consistent with using the BBD index. However, our measurement shows the larger effects than the BBD index does. For example, investment and output are estimated to slightly fall to around 1% and 0.02% in the case of using the BBD index, respectively. This implies that our measurement, capturing the comprehensive dimensions of monetary policy uncertainty, provides better the role of monetary policy uncertainty in explaining economic fluctuations.

Using a factor agumented VAR model

The challenge emerged from VAR analysis is that estimates of impulse response functions can be distorted because of not having enough the variables in the analysis (Bernanke, Boivin, and Eliasz 2005). To deal with this problem, we follow Bernanke, Boivin, and Eliasz (2005) to estimate again our model using a factor augmented VAR as follows:

$$
\begin{aligned}
&X_{it} = b_i F_t + \gamma_i MPU_t + v_{it} \\
&Z_t = c_t + \sum_{j=1}^{P} B_j Z_{t-j} + e_t \\
&Z_t = \{F_t, MPU_t\} \qquad (3.14) \\
&\mathrm{Cov}(v_{it}) = R \\
&\mathrm{Cov}(e_t) = \mathrm{Q}
\end{aligned}
$$

The first equation in (3.14) is the observation equation. X_{it} are the macroeconomic and financial variables of interest, which are driven by common factors F_t and the monetary policy uncertainty MPU_t. The second equation in (3.14) is the transition equations. Because F_t is the latent variable, we follow Bernanke, Boivin, and Eliasz (2005) to use Bayesian likelihood method and Gibbs sampling to simultaneously estimate the common factors and the dynamics in the context of a state space model. We estimate (3.14) using two lags length and three common factors F_t[20]. Our interest is the responses of 18 macroeconomic and financial variables of X_{it} in the observation equation following monetary policy uncertainty shock MPU_t in the transition equation.

Turning to the empirical results, we first find that stock market is estimated to be significantly negative after monetary policy uncertainty. In particular, the S&P 500 index declines around 0.05% following monetary policy uncertainty. We also confirm that investment, consumption and output respond negatively to monetary policy uncertainty shock. This finding is also consistent with the results of the VAR model. By declining investment and consumption, we also expose that export,

[20] Our empirical results are consistent with: (i) using the diffident lags length, (ii) using the different number of the common factors F_t.

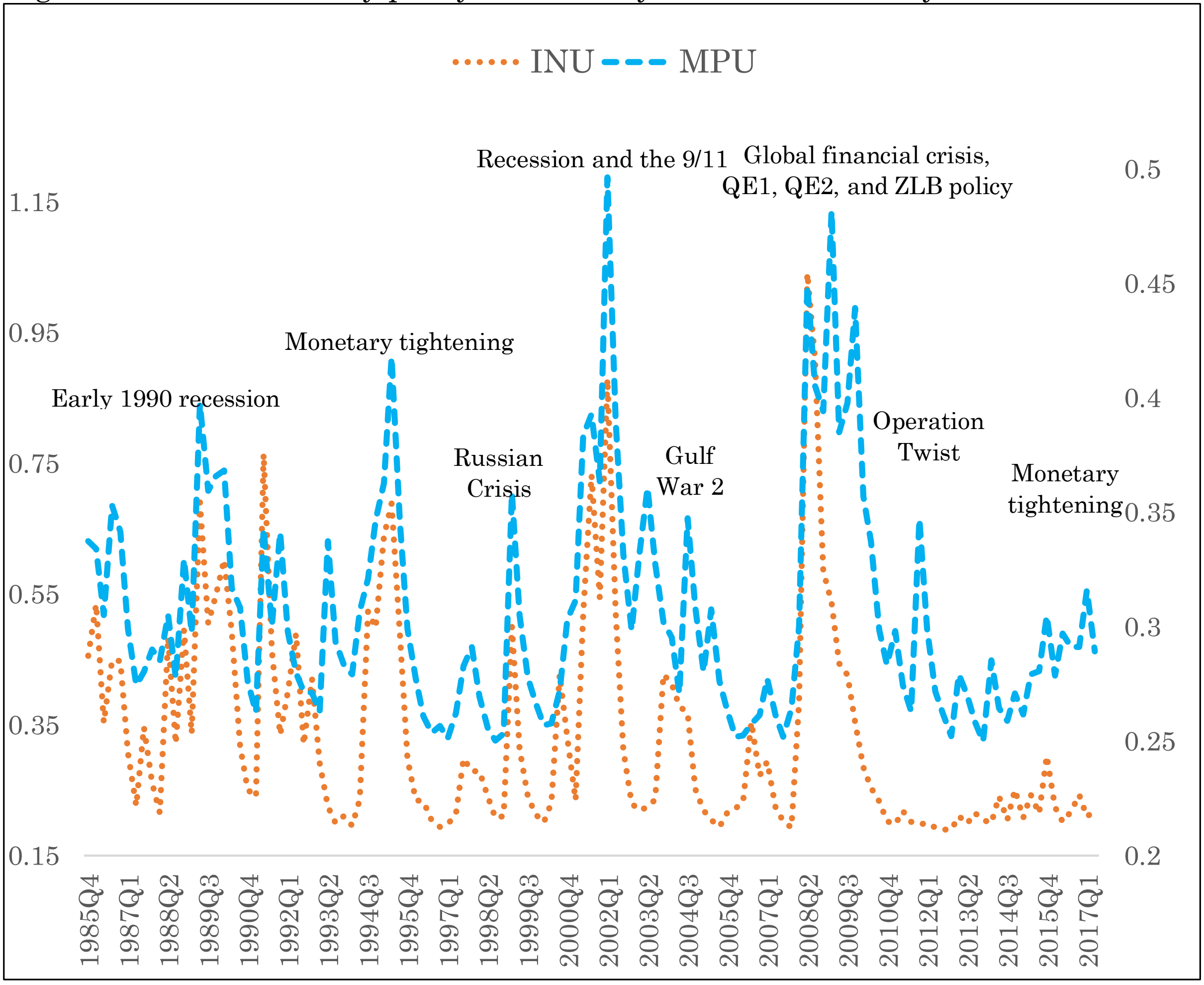
import, real wage, housing price index, and employment also drop considerably following monetary policy uncertainty. The details of empirical results of the factor augmented VAR are provided in Appendix 3.7.

3.5. Conclusions and suggestions

This paper proposes a simple econometric method for measuring monetary policy uncertainty. Our measurement is combined from three resources, including the uncertainty about interest rate, quantitative easing policy, and central bank's communication, based on an univariate GARCH(1,1) with principle component analysis. We find that our monetary policy index is well fitted with the experience of monetary policy uncertainty shocks in the US, and highly correlated with other alternative measurements. We further find that monetary policy uncertainty shock significantly impairs to the economy. The estimated results show that investment, consumption, employment, and output are more vulnerable to monetary policy uncertainty shock. We further expose that the effects of monetary policy uncertainty are found to be more sizeable and persistent during the great depression. This finding, therefore, partly helps explain the slow recovery of the global economy after the 2007-2008 global financial crisis.

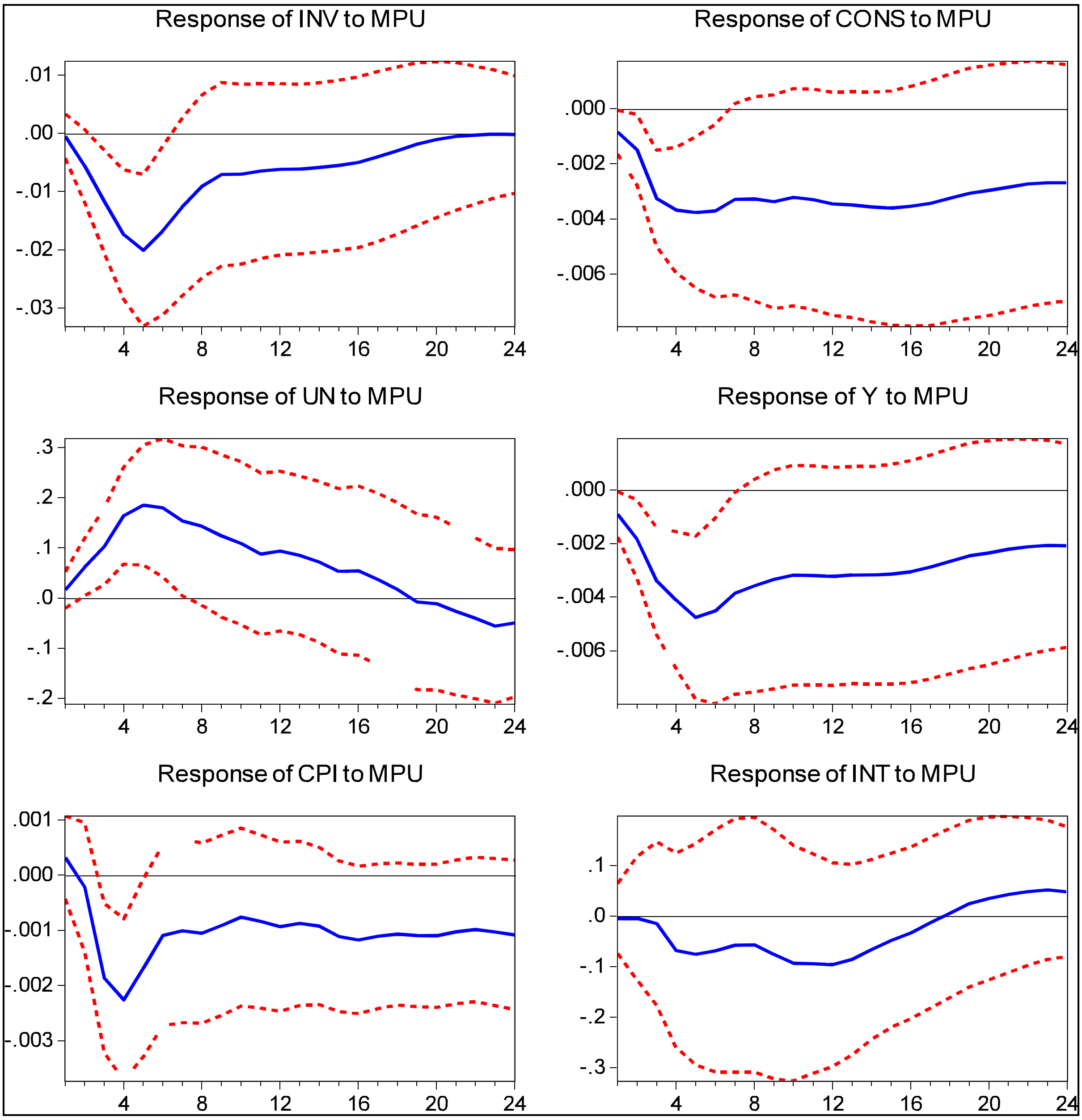
Tables and Figures

Figure 3.1. The monetary policy uncertainty in the US economy.



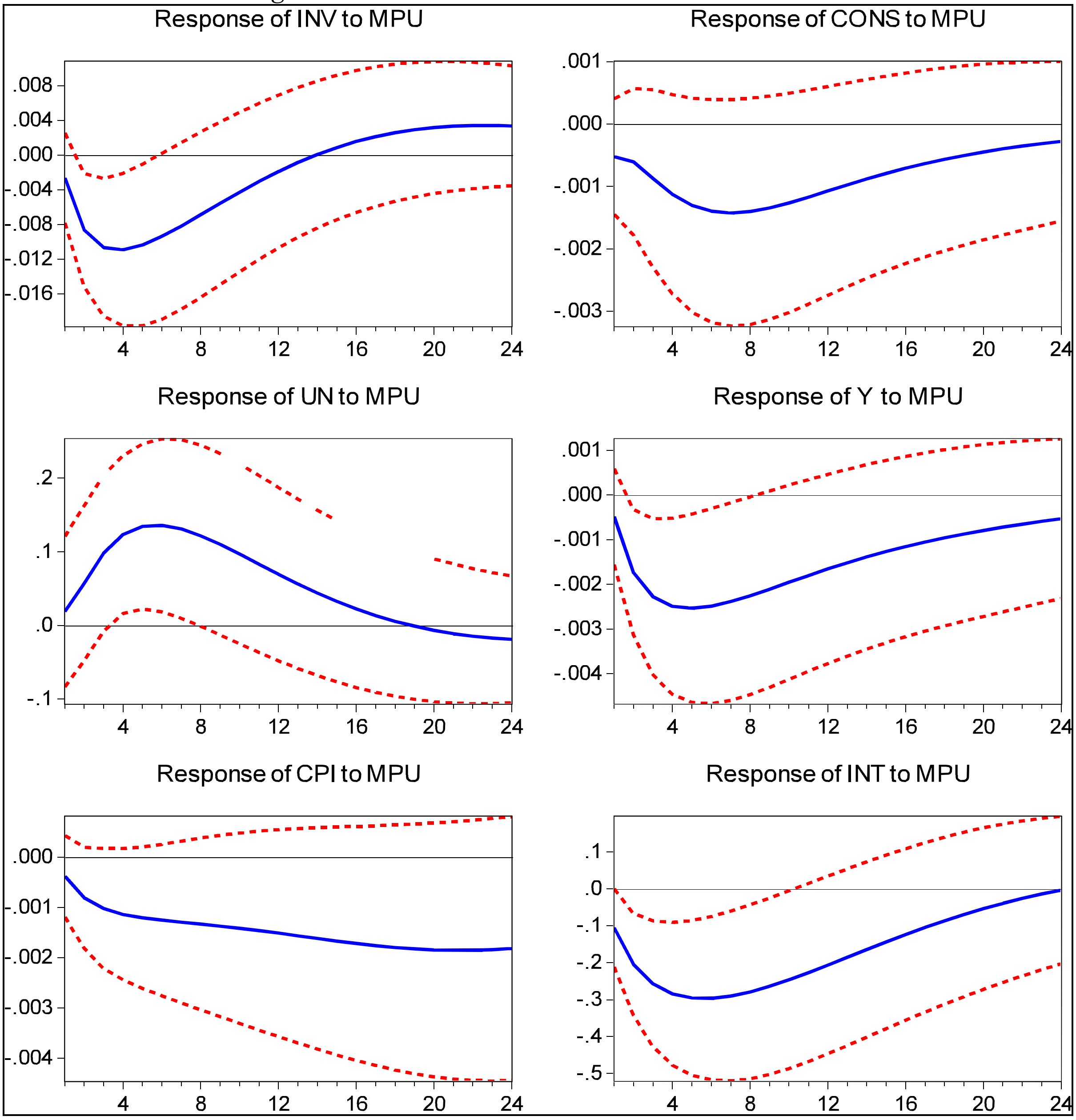
Note: the MPU index is the monetary policy uncertainty index using all the three sources. The INU index is the interest rate uncertainty (u_t) via an univariate GARCH(1,1) model.

Figure 3.2. The effects of monetary policy uncertainty shock on real economic activities.



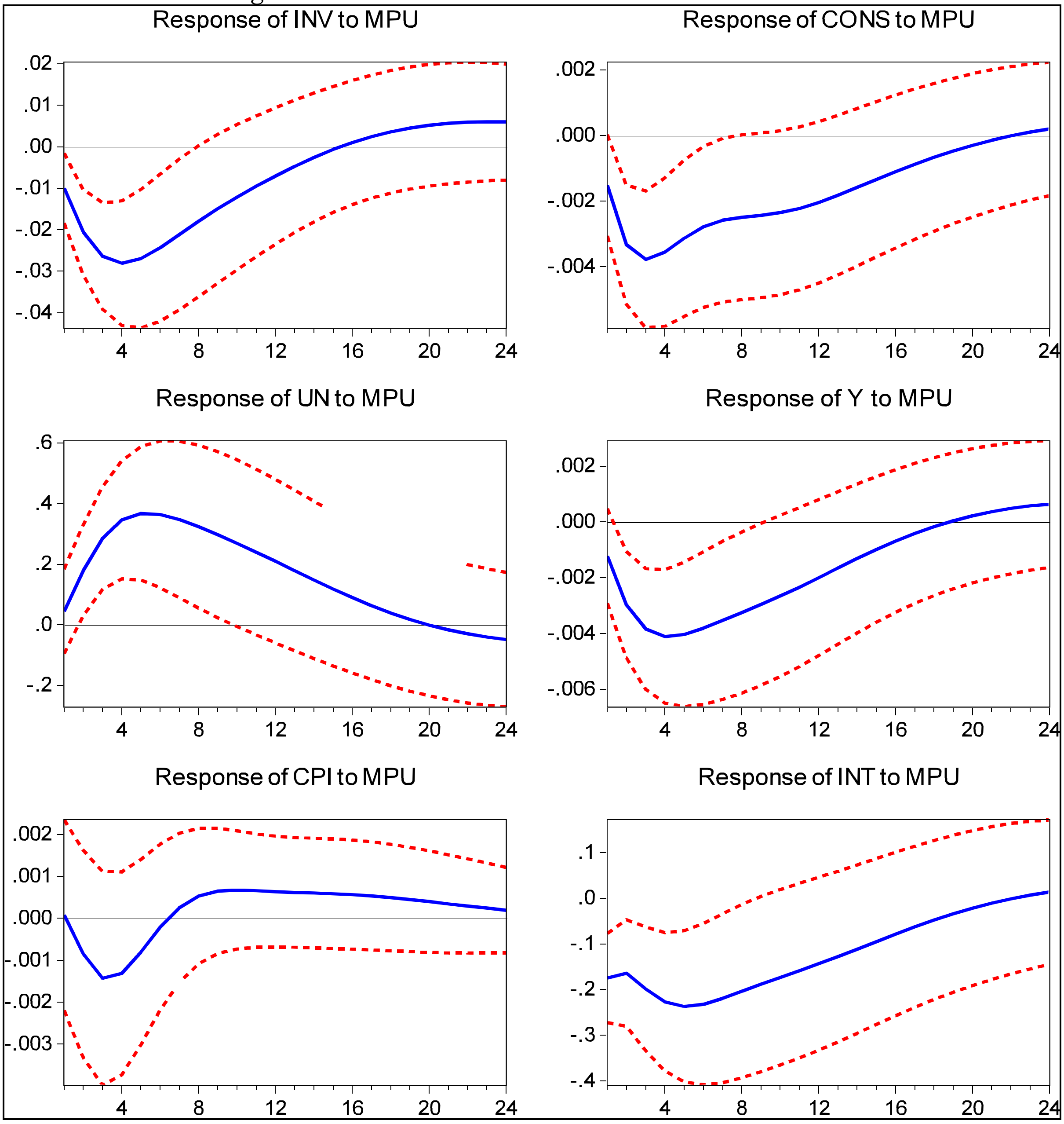
Notes: The blue solid lines display impulse response functions. The red dash lines are the 95% confidence intervals. The vertical axis identifies percent, except for unemployment rate (UN), and short-term interest rate (R). The horizontal axis identifies quarters.

Figure 3.3. The effects of monetary policy uncertainty shock on real economic activities before the global financial crisis.



Notes: The blue solid lines display impulse response functions. The red dash lines are the 95% confidence intervals. The vertical axis identifies percent, except for unemployment rate (UN), and short-term interest rate (R). The horizontal axis identifies quarters.

Figure 3.4. The effects of monetary policy uncertainty shock on real economic activities after the global financial crisis.



Notes: The blue solid lines display impulse response functions. The red dash lines are the 95% confidence intervals. The vertical axis identifies percent, except for unemployment rate (UN), and short-term interest rate (R). The horizontal axis identifies quarters.

Table 3.1. Correlations between our measurement and other alternatives

Correlations	MPU
BBD	0.22
HS	0.35
JLN	0.54
EPU	0.24
VXO	0.40

Note: The BBD is the monetary policy uncertainty index of Baker, Bloom, and Davis (2016). The HS is the interest rate uncertainty based on disagreements among forecasters of Istrefi and Mouabbi (2018). The JLN is the macroeconomic policy uncertainty index of Jurado, Ludvigson, and Ng (2015). The EPU is the economic policy uncertainty index of Baker, Bloom, and Davis (2016). The VXO is the volatility index of 30-day option on the S&P 100 stock index.

Table 3.2. Variance Decomposition

Quarters	INV	CONS	UN	Y	CPI	INT
2	2.99	6.76	4.62	7.2	0.42	0.01
4	14.33	19.61	16.45	18.85	15.6	0.53
6	21.42	21.42	21.6	24.22	17.44	1.05
8	20.58	20.4	22.11	23.82	16.54	1.23
10	18.66	20.18	21.39	23.01	15.75	1.88
12	16.86	19.8	19.53	22.19	15.4	2.69

Appendixes

Appendix 3.1. Empirical results of (3.6)

Table 3.3. Estimation (3.6) with GMM

Dependent Variable: Fed fund rate (i_t)	
Variables	Coefficient
i_{t-1}	0.928*** (0.021)
$(\pi_{t+1}+\pi_{t+2})/2$	0.234** (0.101)
$(y_{t+1}+y_{t+2})/2$	0.091** (0.040)
Constant	-0.147 (0.192)
R-square	0.98
J-statistic	0.86
Prob(J-statistic)	0.35

Note: The values in ( ) represent HAC robust standard errors. *** and ** denote the significance at 1% and 5% level, respectively. We estimate (3.6) using iterated GMM and the lags of the variables as instruments.

Appendix 3.2. Empirical results of (3.7)

Table 3.4. Estimation (3.7) with GMM

Dependent Variable: money supply growth (m_t)	
Variables	Coefficient
m_{t-1}	0.378*** (0.083)
$(\pi_{t+1}+\pi_{t+2})/2$	-0.141** (0.067)
$(y_{t+1}+y_{t+2})/2$	0.0394 (0.04)
Constant	1.237*** (0.171)
R-square	0.18
J-statistic	1.29
Prob(J-statistic)	0.25

Note: The values in ( ) represent HAC robust standard errors. *** and ** denote the significance at 1% and 5% level, respectively. We estimate (3.7) using iterated GMM and the lags of the variables as instruments.

Appendix 3.3. Principle component analysis

Table 3.5. Principle Component Analysis

Principal Components Analysis
Extracting 2 of 3 possible components
Maximum number of components: 2
Eigenvalues: (Sum = 3, Average = 1)

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	1.461	0.513	0.487	1.461	0.487
2	0.948	0.359	0.316	2.410	0.803

Eigenvectors (loadings):

Variable	Principle component 1	Principle component 2
RESID 1	-0.673	0.204
RESID 2	0.667	-0.243
RESID 3	0.316	0.948

Ordinary correlations:

	RESID 1	RESID 2	RESID 3
RESID 1	1.00		
RESID 2	-0.41	1.00	
RESID 3	-0.11	0.10	1.00

Appendix 3.4. Empirical results of GARCH(1,1) for the first two principle component

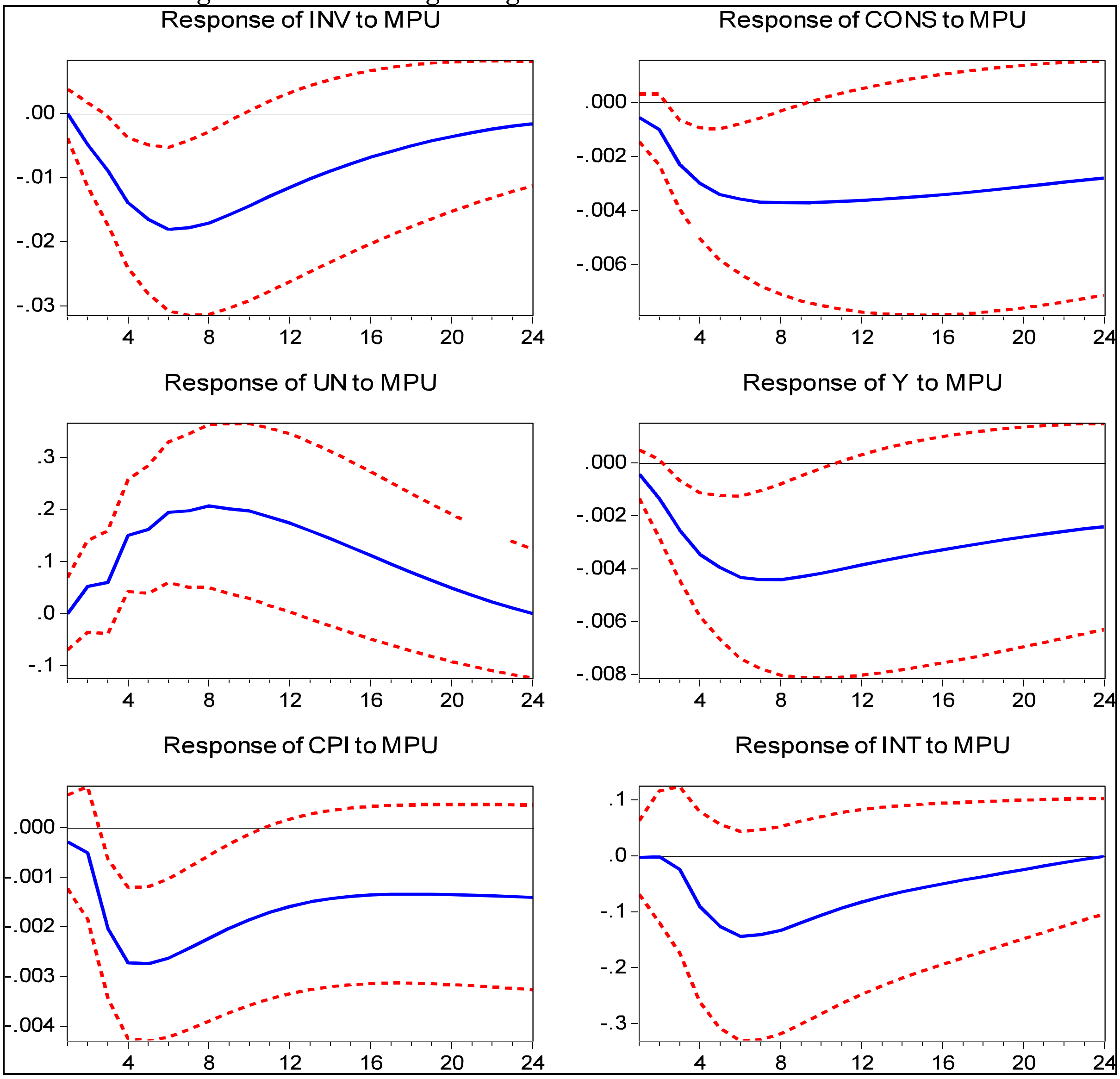
Table 3.6. Empirical results of GARCH(1,1)

Variable	Principle component 1	Principle component 2
ε_t^2	0.194**	0.393***
	(0.09)	(0.141)
σ_t^2	0.498***	0.296*
	(0.166)	(0.169)

Note: The values in ( ) represent robust standard errors. *** and * denote the significance at 1% and 10% level, respectively.

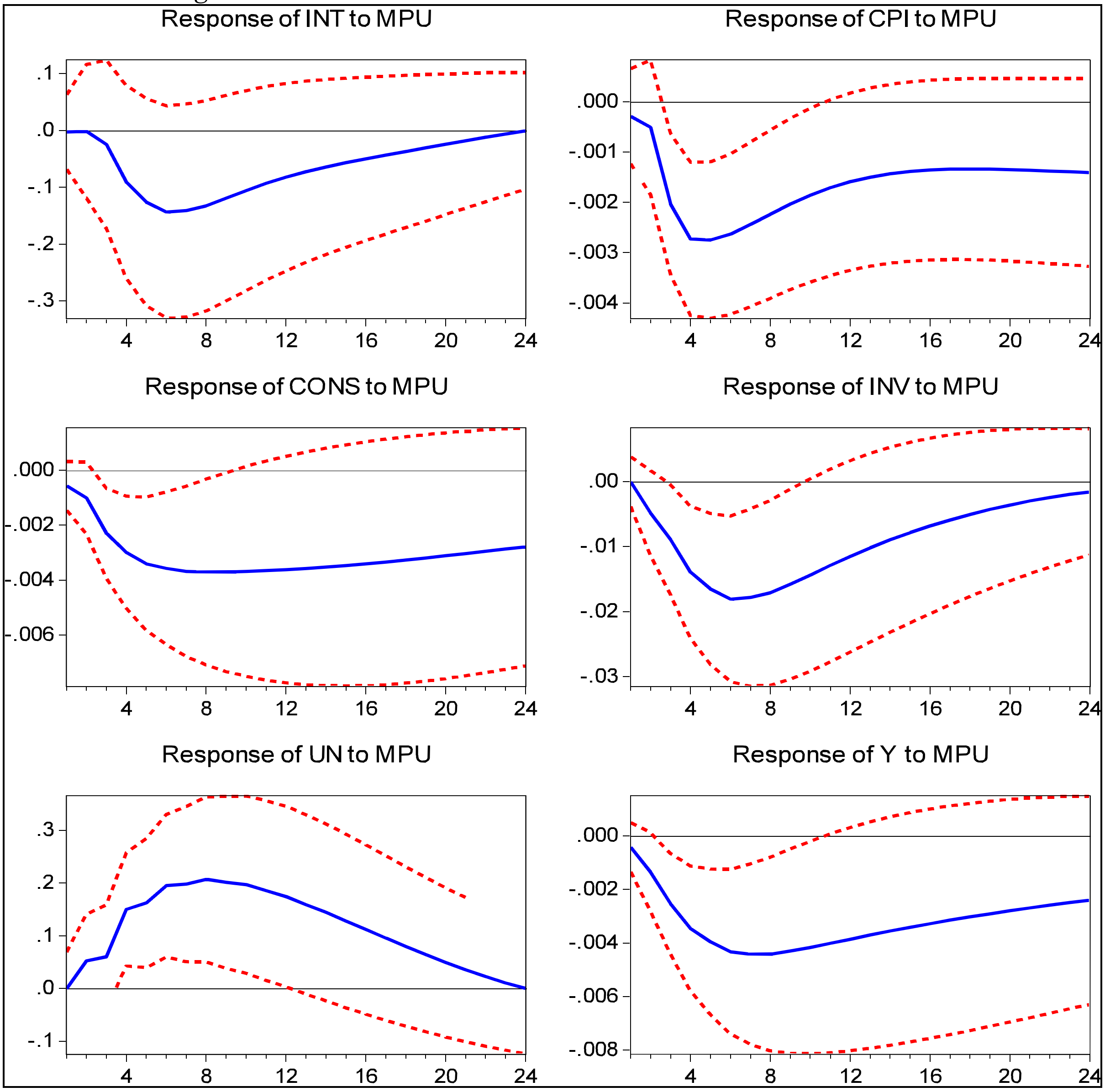
Appendix 3.5. Robustness analysis for the VAR model

Figure 3.5. The effects of monetary policy uncertainty shock on real economic activities using the different lags length.



Notes: we estimate the VAR model using 2 lags length as suggested by SIC criteria. The blue solid lines display impulse response functions. The red dash lines are the 95% confidence intervals. The vertical axis identifies percent, except for unemployment rate (UN), and short-term interest rate (INT). The horizontal axis identifies quarters.

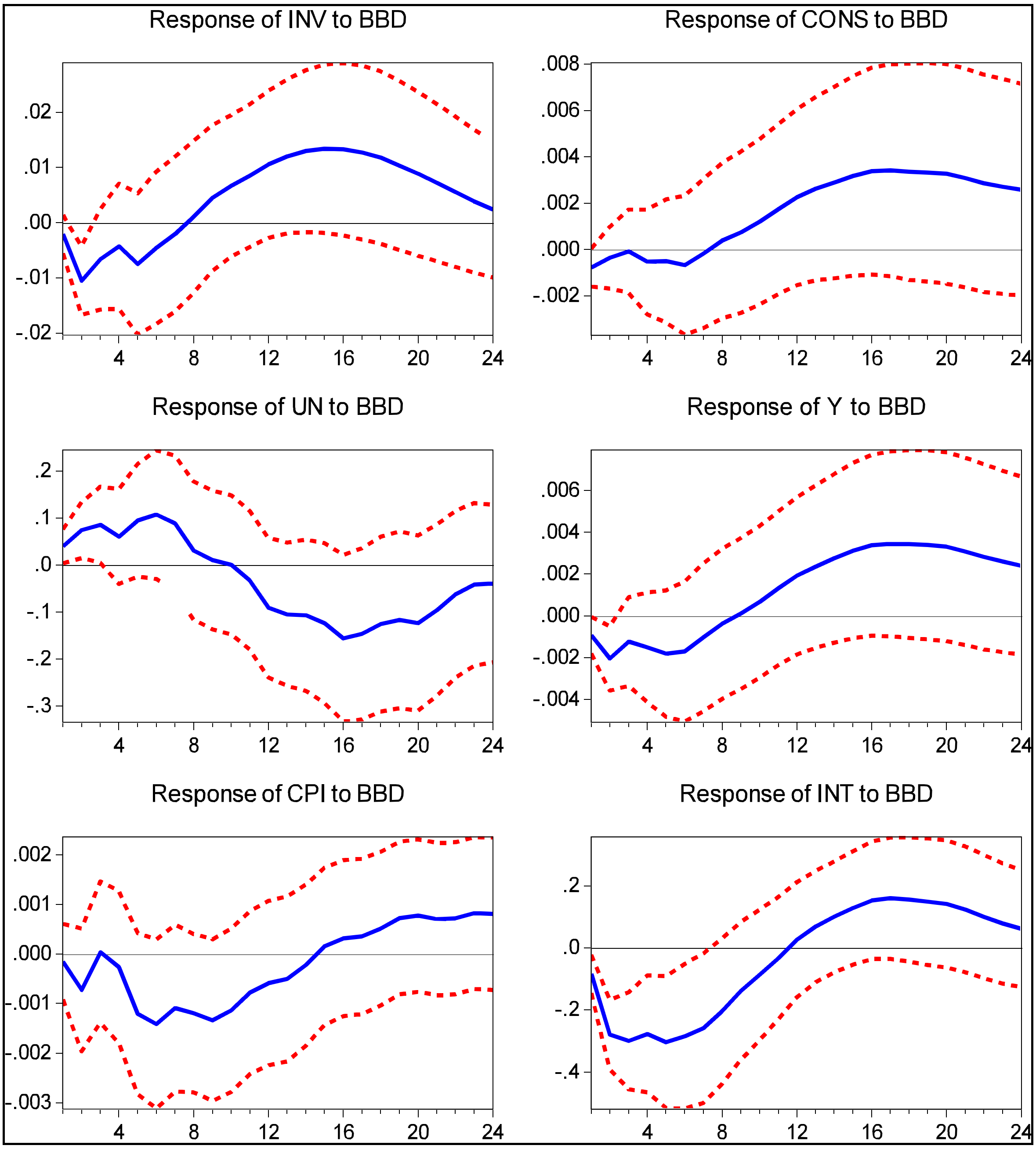
Figure 3.6. The effects of monetary policy uncertainty shock on real economic activities using the different orders of the variables.



Notes: we order the variables as follows: INT, CPI, CONS, INV, UN, and Y. The blue solid lines display impulse response functions. The red dash lines are the 95% confidence intervals. The vertical axis identifies percent, except for unemployment rate (UN), and short-term interest rate (INT). The horizontal axis identifies quarters.

Appendix 3.6. The empirical results using BBD index of Baker, Bloom, and Davis (2016)

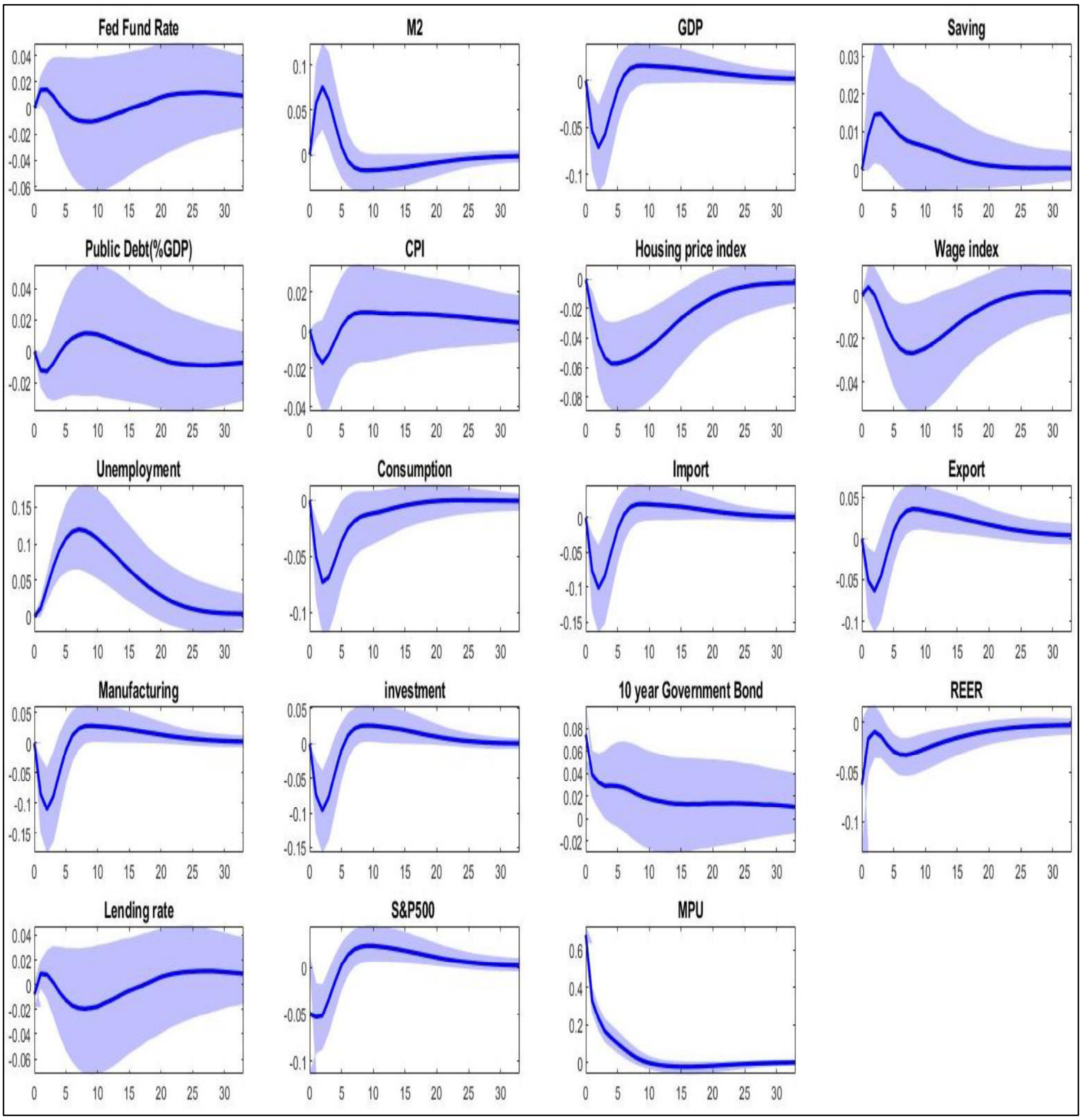
Figure 3.7. The empirical results using BBD index of Baker, Bloom, and Davis (2016).



Notes: we estimate the VAR model using 5 lags length as suggested by AIC criteria. The blue solid lines display impulse response functions. The red dash lines are the 95% confidence intervals. The vertical axis identifies percent, except for unemployment rate (UN), and short-term interest rate (INT). The horizontal axis identifies quarters.

Appendix 3.7. The effects of monetary policy uncertainty in a factor augmented VAR

Figure 3.8. The effects of monetary policy uncertainty shock on economic and financial activities.



Notes: The blue solid lines display impulse response functions. The blue shade areas are the 68% confidence intervals.

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